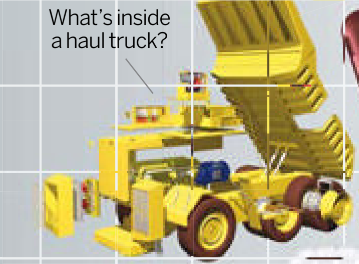
ENGINEERING ENTERTAINMENT DOMESTIC COMPUTING GADGETS INVENTIONS


What's inside a haul truck?

How do games consoles work?

Can an eco bulb save energy?

Does a roller coaster defy gravity?

How does a pistol work?

What are motion sensors?

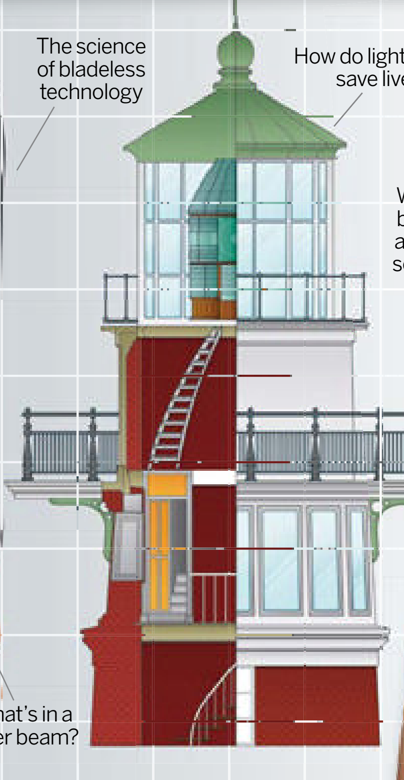
What's inside a DSLR?

HOW IT WORKS BOOK OF

Amazing TECHNOLOGY

Everything you need to know about the world's best tech

The science of bladeless technology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What's behind a touch screen?

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HOW IT WORKS BOOK OF Amazing TECHNOLOGY

Imagine Publishing Ltd
Richmond House
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Dorset BH2 6EZ
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Dave Harfield

Production Editor
Helen Laidlaw

Design
Danielle Dixon, Duncan Crooke

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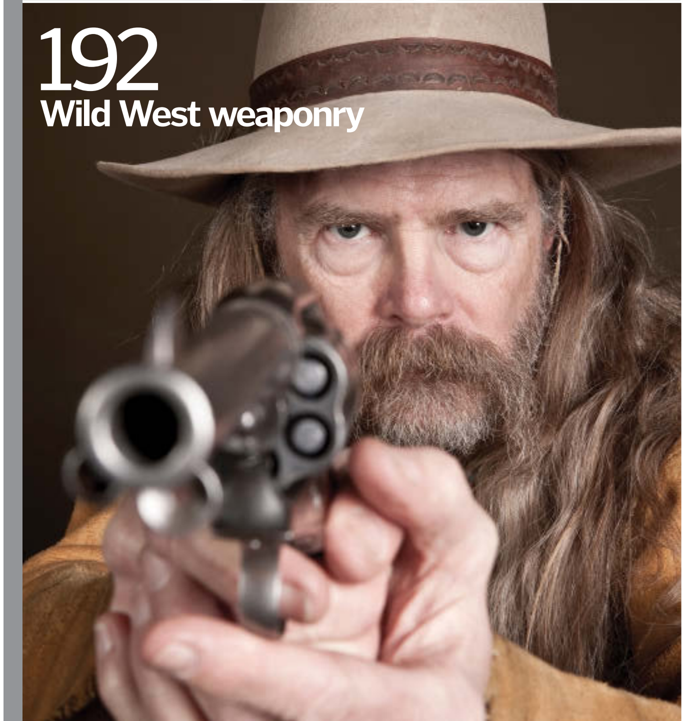

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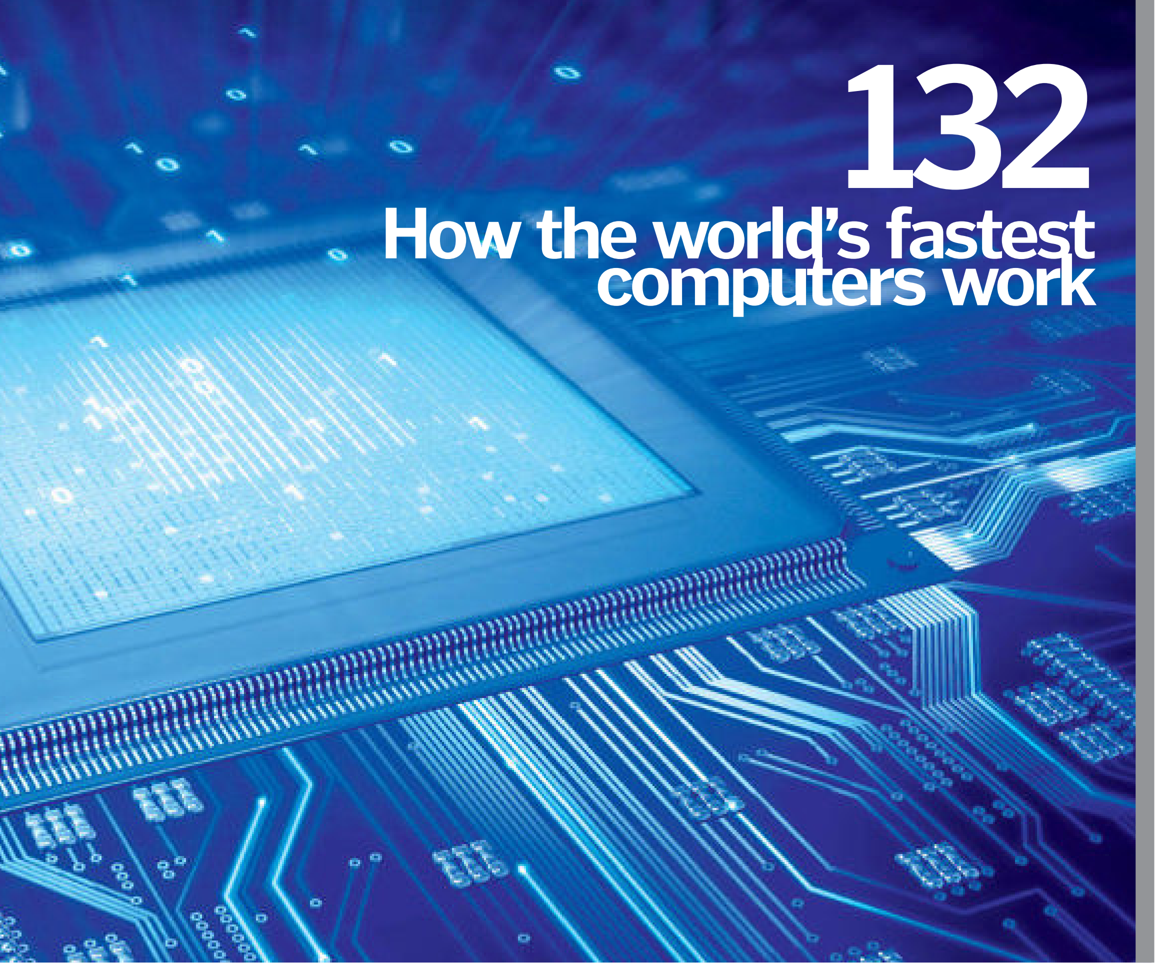

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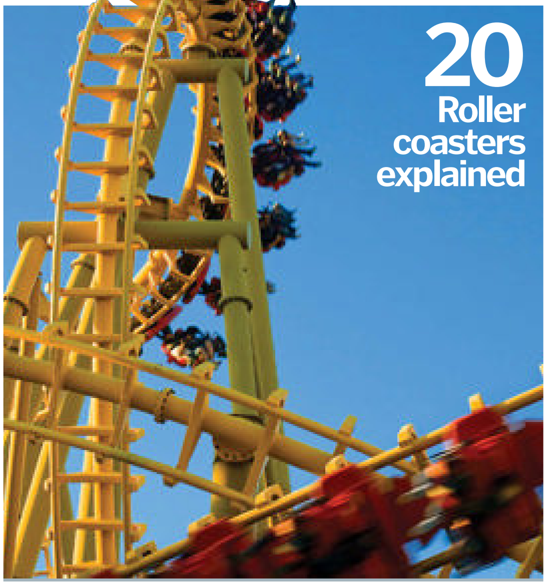

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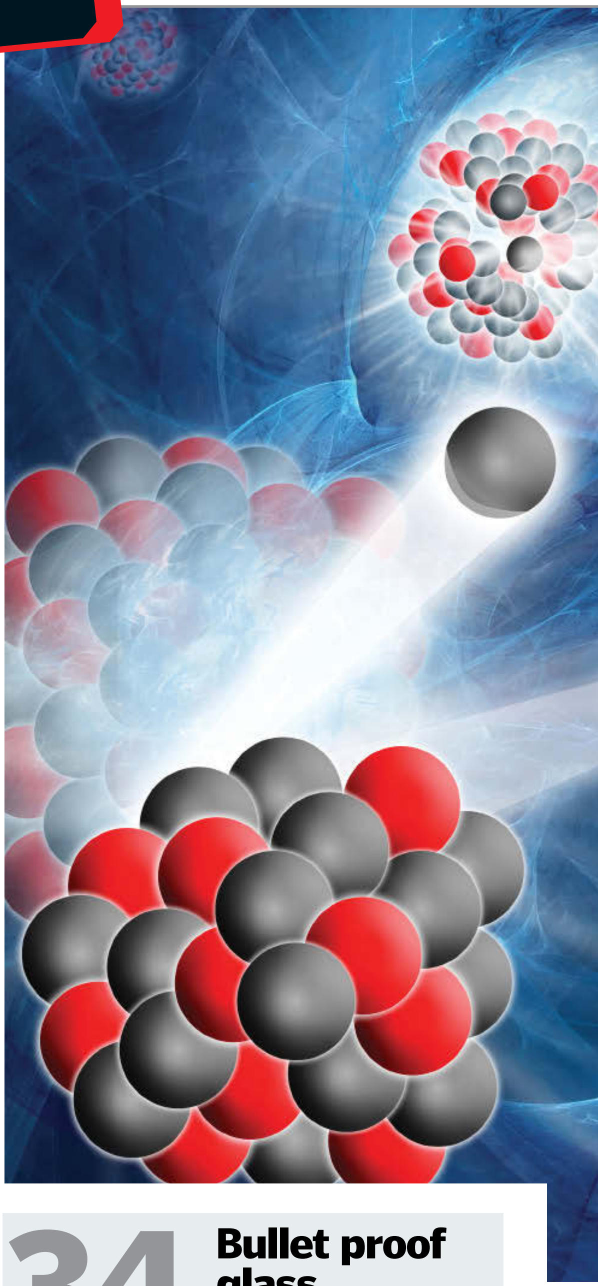

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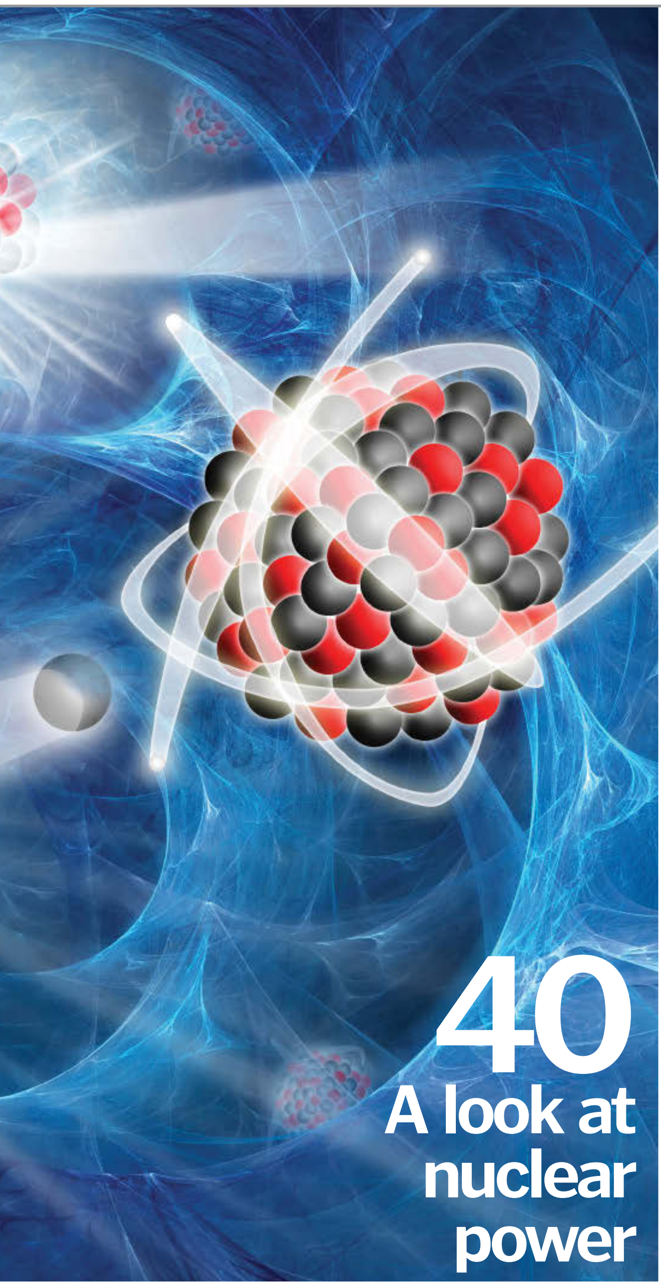

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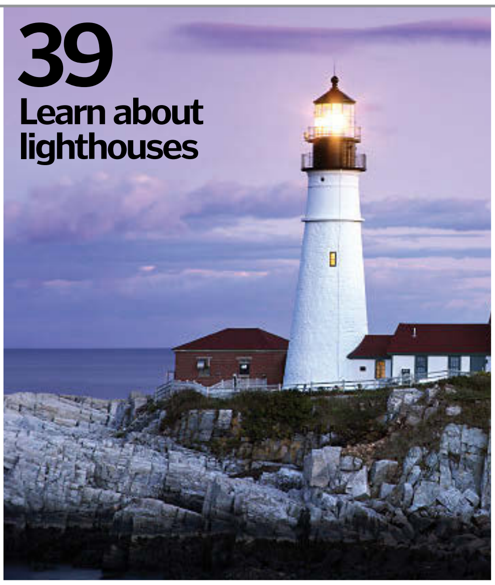

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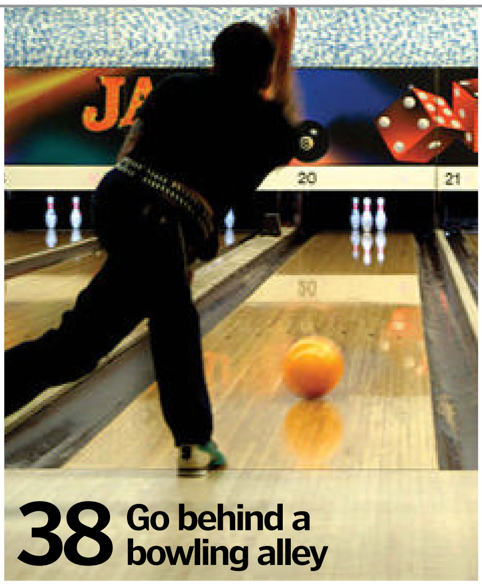

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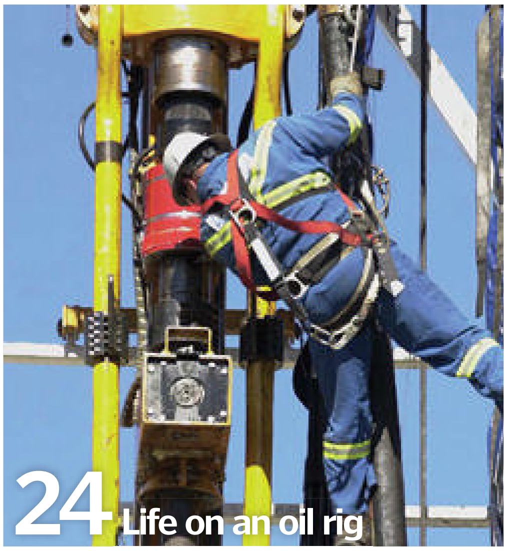

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MASSIVE mining machines

BUCYRUS
8750

© Bucyrus International Inc.

The world is still primarily reliant on fossil fuels for energy generation. With billions of people across the globe, this means the demands that are placed on the mining industry are huge. Extracting these fossil fuels as efficiently as humanly possible is of utmost importance, and for best efficiency and ability to meet this demand, you need scale. And the five machines featured across the next six pages definitely fit the bill scale. This is huge-scale engineering that you can barely get your head around. It's difficult to get your head around just how vast these massive tools are – not to mention the sheer amount of fossil fuels they extract each and every day, around the clock.

They may cost tens of millions of pounds, and last for decades, but when it comes down to it they are still controlled by a human being. The principles they use will be familiar to those who have driven past roadworks or looked closely at a building site. It's just that they are enlarged to dimensions to take your breath away. Read on to find out how they work.

DID YOU KNOW? *The RH400 is the world's largest hydraulic excavator*

The mining industry is all about scale. And when we say these machines are big, we mean BIG!

BIGGEST DRAGLINE

Bucyrus 8750

This massive dragline can clear football pitch-sized spaces right before your eyes

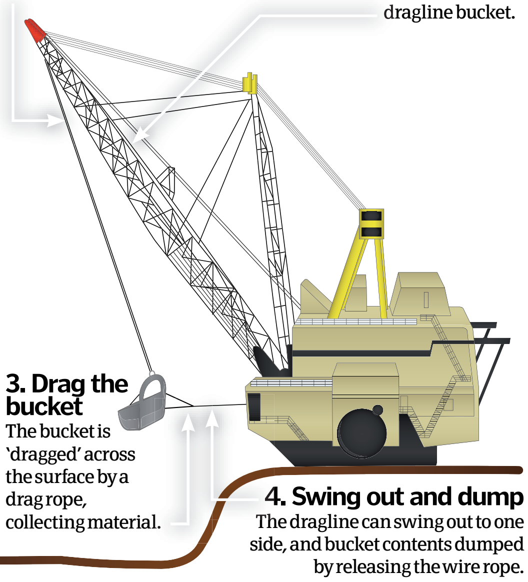
The Bucyrus Dragline 8750 will run 24 hours a day, seven days a week, and excavate up to 116m³ per scoop – that's the equivalent of 58,000 two-litre water bottles. It will do this for an average of 40 years, which is why it's used in surface mining operations worldwide. There are 45 different specifications of dragline, each with its very own on-staff application engineer.

The 8750 series has multiple bucket capacities, and a boom length of up to 132.5m. It can reach depths of up to 79.8m. It is among the largest of all mobile equipment in the world; but when we say mobile, we do not mean fast! Moving a dragline is not the work of a moment, particularly the Bucyrus. It has a rated suspended load of up to 344,736kg and its approximate working weight is more than 7.5 tons.

It is powered by Siemens AC drives throughout. The 8750 series comes in various guises, with the range-topper being the 8750D3. This uses gearless AC direct drive for hoist and drag – the advantages here are in efficiency. It allows fast bucket fills, and the lack of hoist and drag gearing also reduces maintenance.

Power is provided to the AC drives by utility lines – the enormous power consumption means that connection directly to the electrical grid is often the most efficient solution.

How a dragline excavator works

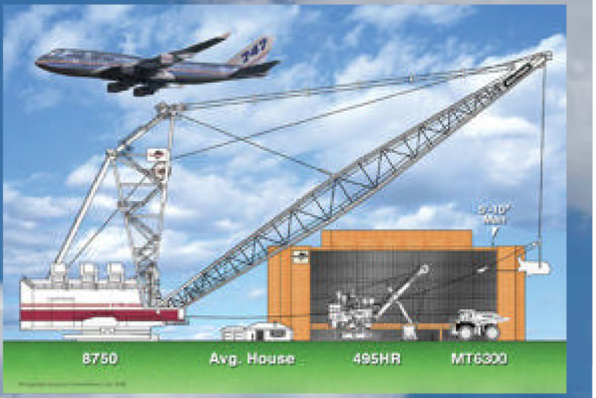


1. Hoist the bucket
A bucket is suspended on a hoist coupler from the dragline's boom arm by strong hoist wires.

2. Boom arm
The hoist rope drops down from the top point of the boom arm; connected to it is the dragline bucket.

3. Drag the bucket
The bucket is 'dragged' across the surface by a drag rope, collecting material.

4. Swing out and dump
The dragline can swing out to one side, and bucket contents dumped by releasing the wire rope.



How big?!

Just in case you have trouble getting your head around just how massive this machine is...

AC ace
The AC drives in the Bucyrus are 86 per cent efficient, compared to 74 per cent efficiency for DC drives.

On the grid
Most draglines are connected direct to the electrical grid because of the sheer hunger they have for power.

Cutting-edge drive
The cutting-edge D3 direct drive technology is even more efficient, with an 89 per cent efficiency stat.

BUCYRUS 8750
BUCYRUS

The Statistics

Bucyrus 8750

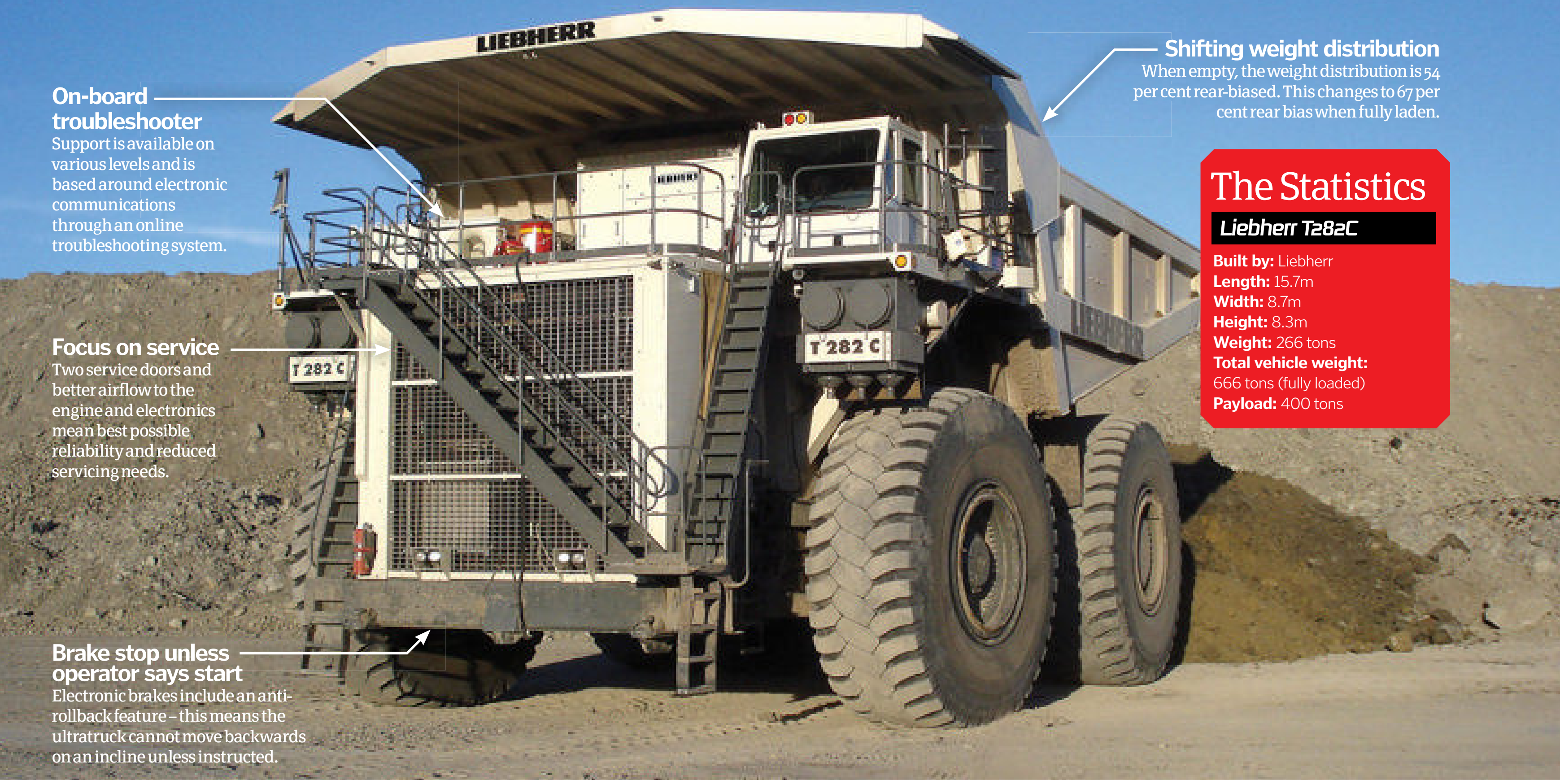
Built by: Bucyrus
Overall length: 140m
Width: 39m
Overall height: 80m

> "The T282C has up to 20 cylinders and a 95.4-litre capacity. Maximum power is 4,023bhp"

BIGGEST HAUL TRUCK

Liebherr T282C

This supertruck is the biggest of its kind in the world – a monster mining truck no mine can defeat



On-board troubleshooter
Support is available on various levels and is based around electronic communications through an online troubleshooting system.

Focus on service
Two service doors and better airflow to the engine and electronics mean best possible reliability and reduced servicing needs.

Brake stop unless operator says start
Electronic brakes include an anti-rollback feature – this means the ultratruck cannot move backwards on an incline unless instructed.

Shifting weight distribution
When empty, the weight distribution is 54 per cent rear-biased. This changes to 67 per cent rear bias when fully laden.

The Statistics

Liebherr T282C

Built by: Liebherr
Length: 15.7m
Width: 8.7m
Height: 8.3m
Weight: 266 tons
Total vehicle weight: 666 tons (fully loaded)
Payload: 400 tons

The word 'supertruck' is not enough to describe the 'ultratruck' behemoth that is the Liebherr T282C, which is used in mining operations worldwide. Its sheer scale can be judged by its empty weight of 266 tons – or more than 150 Ford Focus hatchbacks piled together. Not only that, but it's also capable of carrying a 400 ton payload on top of this, giving it a weight of over 600 tons when full!

Powering it is a diesel engine that comes in either fuel-optimised or emissions-optimised setup. As with passenger cars, achieving lowest-possible exhaust emissions carries a fuel usage penalty. It has up to 20 cylinders and a 95.4-litre capacity; maximum power is 4,023bhp! The engine alone weighs 12 tons. It delivers energy to an alternator, which powers a liquid-cooled control box – this converts it into three-phase AC current.

It is moved by an AC electronic drive system called IGBT – insulated gate bipolar transistor. This uses in-wheel induction motors to move the monster truck. They allow the diesel to run independently of travel speed, therefore generating drive in the most efficient way possible. This gives better fuel economy.

The IGBT drive system can also slow the big truck down instead of using the back-up disc brakes. This regenerates electrical energy, which is used to power the truck's auxiliary systems – it is hybrid-style ecological awareness!

Road construction dumper truck drivers will find the cabin of this beast fairly familiar: it has a traditional steering wheel and pedals, and the left-hand-drive set-up includes a 30-cm colour touch screen for diagnostics. Its top speed is 64km/h (40mph) and the clever drive system even aids handling. In corners, drive to the outside rear wheels is increased and eased off on the inside wheels, helping it turn in better.

The T282C is constructed using a vertical integration process. On the cast truck frame sits the massive dump body, superstructure and drivetrain. Liebherr has optimised it using computer aided design, so reinforcements are only added in high stress areas. This has cut weight and also improved the maximum payload. The dump system is controlled using a joystick and completes a lift cycle in under 50 seconds. Fully lifted, the dump body stands nearly 15m high.

LeTourneau

Multi-purpose digger
The LeTourneau can be used to load rock, coal and iron ore. It can lift up to 72,574kg.

On the fast cycle
The entire load cycle takes just 25 seconds – 16 seconds for hoist, three seconds for dump and a six-second float.

© LeTourneau

5 TOP FACTS
TYPES OF MINING

Open-cast mining
1 In open-cast mining the minerals that lie on the surface of the earth or very near the surface are scooped and scratched out from the surface by machines like these.

Open-pit mining
2 Open-pit mining consists of recovery of materials from an open pit in the ground, quarrying or gathering building materials from an open-pit mine.

Strip mining
3 Similar in many ways to open-pit mining, this consists of stripping surface layers off to reveal the ore and seams that lie underneath.

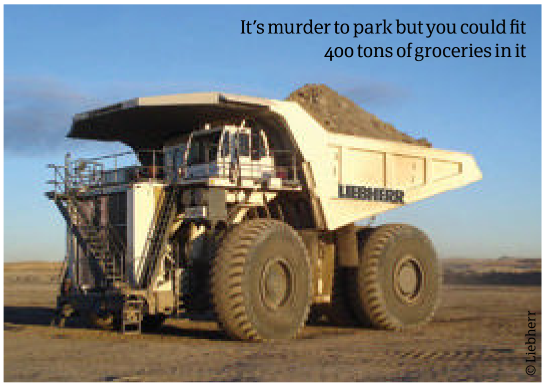
Mountaintop removal
4 Commonly associated with coal mining, this involves taking the top of a mountain off to reach deposits at depth.

Sub-surface mining
5 Digging tunnels or shafts into the earth to reach buried ore deposits. Ore for processing, and waste rock for disposal are brought to the surface through the tunnels.

DID YOU KNOW? The T282C has a payload of up to 400 tons

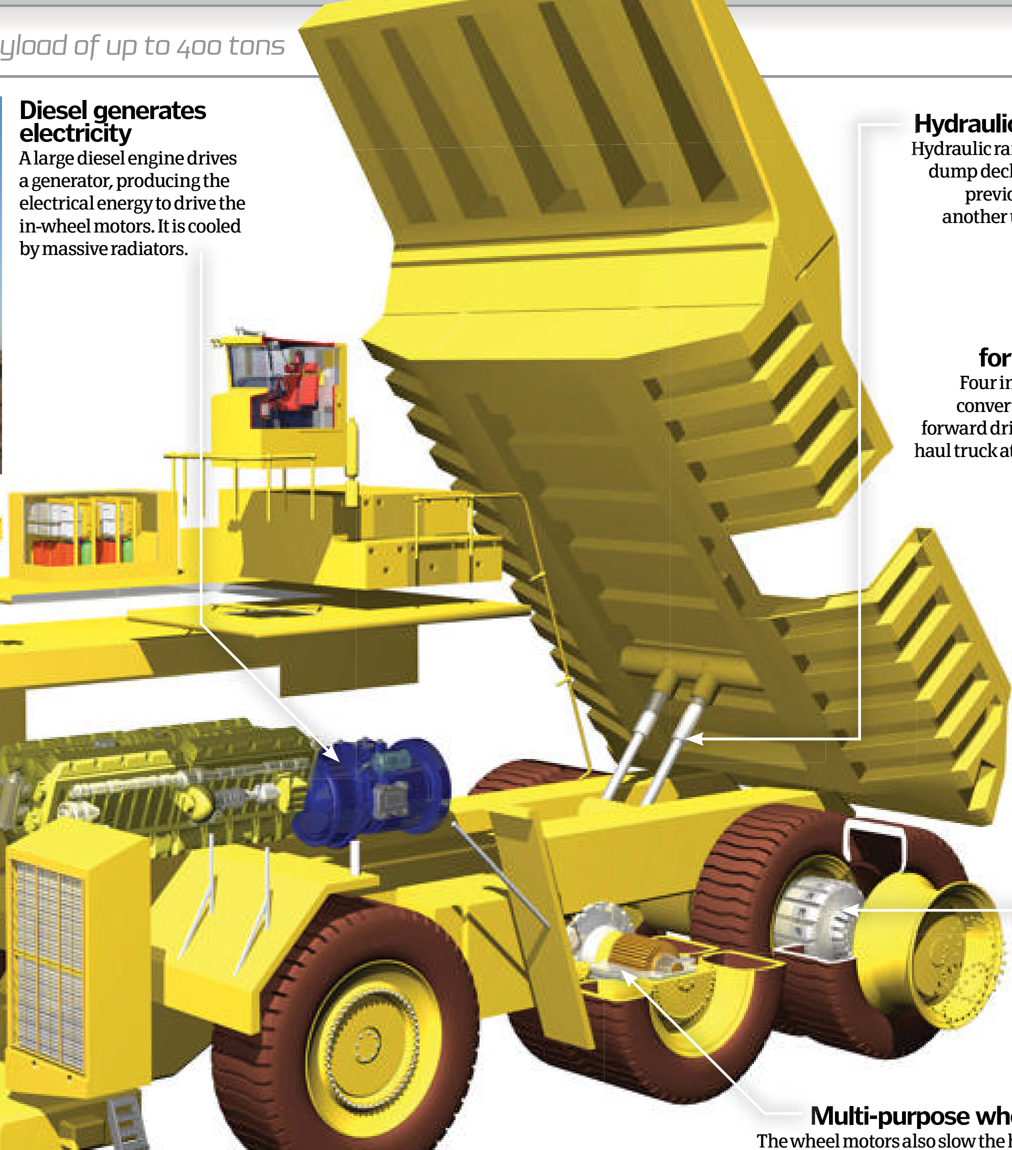
Anatomy of a haul truck

Get under the hood of a Terex Titan


It's murder to park but you could fit 400 tons of groceries in it

© Liebherr

© Liebherr


© Alex Pang

Diesel generates electricity
A large diesel engine drives a generator, producing the electrical energy to drive the in-wheel motors. It is cooled by massive radiators.

Hydraulic ram lifter
Hydraulic rams lift the haul dump deck that has been previously loaded by another ultra-machine.

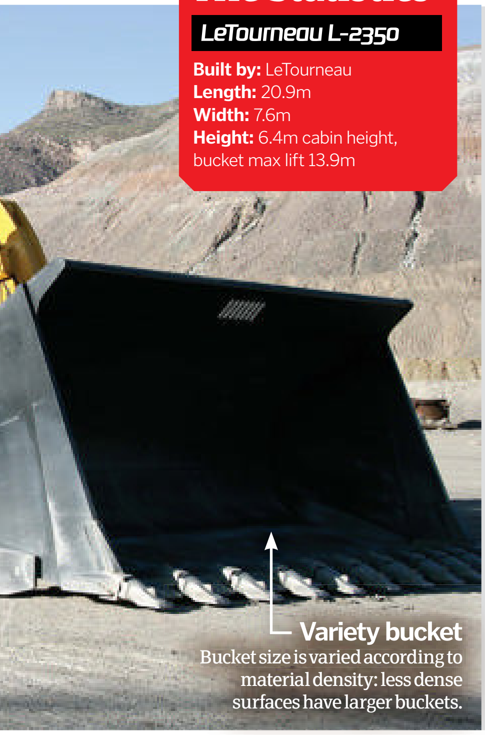
AC into forward drive
Four in-wheel motors convert AC power into forward drive, moving the haul truck at up to 64km/h.

Multi-purpose wheel motors
The wheel motors also slow the haul truck, and in doing so, also regenerates electrical energy.

The Statistics

LeTourneau L-2350

Built by: LeTourneau
Length: 20.9m
Width: 7.6m
Height: 6.4m cabin height, bucket max lift 13.9m


Variety bucket
Bucket size is varied according to material density: less dense surfaces have larger buckets.

BIGGEST WHEEL LOADER
LeTourneau L-2350

These 'worker ants' are often seen on building sites – but it's not often you see one on this scale!

To clear large spaces fast, you need a LeTourneau L-2350. It's the world's biggest wheel loader, and is more than 20m long. The wheelbase alone is the length of two large executive cars, and the bucket is so big it is nearly a metre wider than the wheel loader truck itself. It is driven by a choice of several diesel engines, depending on the type of material to be excavated – it is highly flexible but used mainly in coal mining. The largest engine is 45 litres and puts out 2,300hp.

Maximum speed is 17km/h (10.5mph), both forwards and backwards; an AC-DC traction drive uses four traction motors with infinitely variable speed. Braking is electronic and the L-2350 is steered by a joystick. Excavation operations use an electrohydraulic hoist and bucket; the best-match truck capacity is 400 tons and larger! As it operates in mines, all air is filtered and supplied to the engine, drive system cooling and also a pressurised cabin. Operators have a colour-coded warning light system that alerts them to engine, hydraulic, electrical and electronic problems.

The operating payload is vast, up to 72,574kg in standard form, and only slightly reduced at 68,039kg in high-light form. As standard, it has a reach of 3.18m, with the high-lift increasing this to 3.49m (and a total height of 13.89m).

"The RH400 has a bucket capacity of $50m^3$"

BIGGEST HYDRAULIC LOADERS

Terex (now Bucyrus) RH400

Everything about the Bucyrus hydraulic excavator is huge – as you'd imagine of something that weighs nearly 1,000 tons!

In front of you is the world's largest hydraulic excavator – an $11m machine that stands a full ten metres (33 feet) high and 8.6 metres wide. The record-breaking Bucyrus is used for many mining operations, including coal, copper, iron ore and oil sands; it is commonly found in Canada, but also has an underground coal-mining specification.

The RH400 weighs an incredible 980 tons and is powered by two turbodiesel engines with a maximum output of 4,500bhp at 1,900rpm. Each is 60.2 litres in capacity and has 16 cylinders; they use two-stage turbocharging, aftercooling and intercooling.

The engines power hydraulic pumps, which generate very high pressure oil for driving the track motors and moving the excavator rams. There are eight main pumps and six swing pumps. Forward drive is via axial piston motors on each side; each track is two metres wide and three metres high. The total hydraulic oil volume is 13,000 litres; an electronic Pump Managing System oversees the hydraulics and incorporates flow-on-demand control.

Excavators are built of two distinct constructions – the undercarriage and the house, where the operator cab and boom reside. They fit to the undercarriage using a centre pin, meaning they can rotate 360 degrees. A torsion-resistant 9.5m-long boom and 56m-long stick provides the excavation shovelling duties; the bucket is attached on the end. The RH400 has a bucket capacity of $50m^3$, and various specifications are available, depending on shovelling duties: iron ore, heavy rock, oil sand and standard rock configurations are offered. Up to 3,300kN of digging force can be generated.

It achieves considerable bucket load without significant counterweights at the rear. This means it is relatively compact, which is an important consideration for use in space-restricted areas. The operator also has a comfy cabin with pneumatic seat and ergonomic joystick control system. The windscreen is armour plated and a safety switch is embedded inside the seat: when it senses it is unoccupied, all the hydraulic controls are automatically neutralised.

Low speed, high power
The maximum speed of the RH400 is 2.2km/h (1.37mph); it can, however, generate a maximum tractive force of 4,140kN…

Eco engines
The diesel engines pass US EPA emissions laws; they are fed by a 15,100-litre diesel fuel tank.

The Statistics

Terex RH400

Built by: Bucyrus
Length: 10.98m
Width: 8.6m
Height: 9.99m

DID YOU KNOW? *A rope shovel is used for digging out surfaces such as vertical coal faces*

BIGGEST ROPE SHOVEL

P&H 4100XPC

Even the largest rock faces in the world should fear this huge rope shovel

Rope shovels are the heavy-duty attackers of the mining industry – and none eat away the earth faster than the P&H 4100XPC. This is the supercharged high-performance pinnacle of the rope shovel world!

A rope shovel is used for digging out surfaces such as vertical coal faces. They consist of a rotating deck where the driver cabin lies, along with the engine and a heavy counterweight. To the front of the deck a boom is attached, which carries a swing arm and a bucket.

The bucket is controlled by a series of ropes. When facing a surface to be excavated, the wire ropes are dug into the surface using a crowd arm, then pulled up through filling it with material. Once raised clear, it swings to one side and can be released into a dumper truck. P&H has cut seconds from this entire cycle with its ultra shovel. How? Through speeding up the hoist cycle by extending the shovel's speed range.

This has come at no penalty to capacity or payload, though. The nominal payload is 115 tons, and it can cut up to 16.8m high, through a radius of 23.9m. This is why the operator sits a full ten metres off the ground; the rope shovel itself is 14.7m high, and 15m long. The wire hoist rope alone is 73mm thick!

There are two hoist motors, rated at a peak 3,990hp, three swing motors, two propel motors and a single crowd motor. The operator controls it via an armrest-mounted pistol-grip joystick.

The Statistics

P&H 4100XPC

Built by: P&H
Length: 32m
Width: 14.4m
Height: 21m

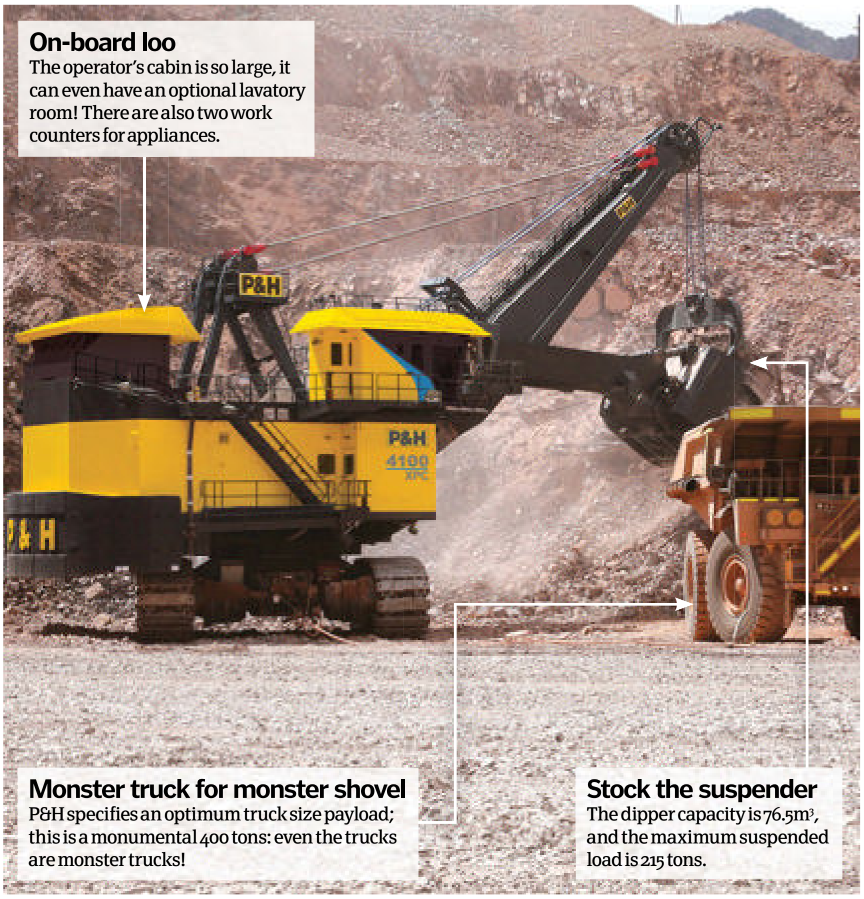
More of a bungalow-load than a shed-load

Comes in a range of colours, including this fetching burgundy

Low on service
Bucyrus has fitted a xenon working light. It is ultra-bright for working around the clock. Servicing is minimal and oil change intervals are 1,000 hours.

© Bucyrus International Inc.

Mining Magazine
A big thanks goes to Paul Moore, editor of Mining Magazine, for his help researching this article.
www.miningmagazine.com

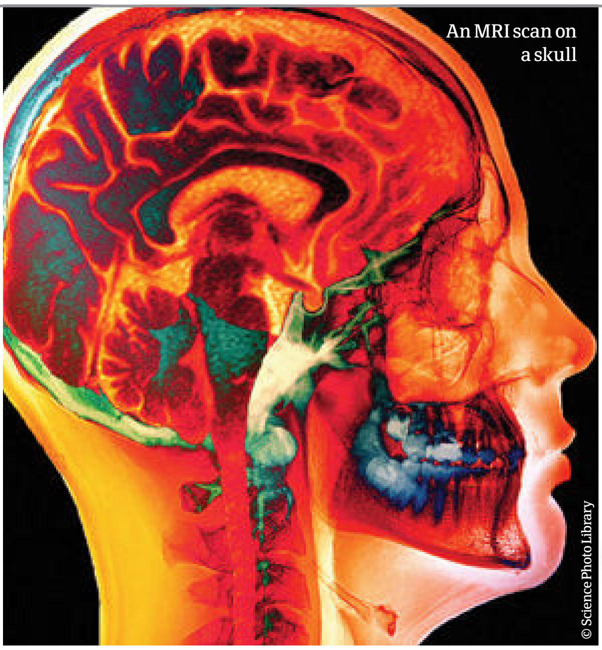

On-board loo
The operator's cabin is so large, it can even have an optional lavatory room! There are also two work counters for appliances.

Monster truck for monster shovel
P&H specifies an optimum truck size payload; this is a monumental 400 tons: even the trucks are monster trucks!

Stock the suspender
The dipper capacity is 76.5m^3, and the maximum suspended load is 215 tons.

© PH Mining Equipment

> "Physicists and engineers use and manipulate the basic laws of physics"


An MRI scan on a skull

© Science Photo Library

Best of both worlds
Using magnets produces high-quality images at virtually no risk to the patient.

Inside an MRI scanner

When doctors need the highest quality images possible they turn to MRI scanners, but how do they work?

Doctors often plan treatments based on imaging. X-rays, ultrasound and CT scans provide useful pictures, but when the highest quality images are needed, they turn to MRI scanners. While CT scanners use x-rays and therefore expose the patient to radiation, magnetic resonance imaging (MRI) uses powerful magnets and is virtually risk free.

MRI scans are obtained for many medical conditions, although since they are expensive and complicated to interpret, they certainly aren't as easy as taking a chest x-ray. Examples for which they are used include planning surgery for rectal cancers, assessing bones for infection (osteomyelitis), looking at the bile ducts in detail for trapped gallstones, assessing ligamental damage in the knee joints and assessing the spinal cord for infections, tumours or trapped nerves.

Physicists and engineers use and manipulate the basic laws of physics to develop these incredible scanners for doctors to use. MRI scans provide such details because they work at a sub-molecular level; they work on the protons within hydrogen atoms. By changing the position of these protons using magnetic fields, extremely detailed pictures of the different types of particles are obtained. Since these pictures rely on the tiny movements of these tiny particles, you need to lie very still during the scan.

Planning from the detail

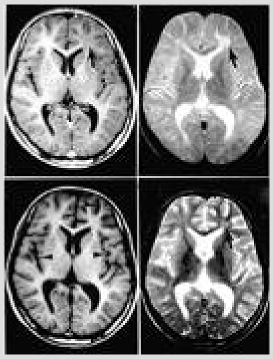
The detail provided by MRI scanners enables doctors of all specialties to plan their treatment. When footballers damage their knees, an MRI scan will tell if the ligaments are ruptured. Knee surgeons can then reconstruct the damage, often via keyhole incisions (arthroscopically). MRI scans are used to characterise a variety of tumours, such as those of the rectum (the lowest part of the colon) and within the brain. MRI gives enough detail to determine the size and stage of the tumour. This helps specialist surgeons plan whether the tumour is resectable, and also how to perform the operation.

MRI's key lies in its ability to differentiate soft tissues – it can even tell the difference between infected and normal tissues. Infections within bones are best identified using MRI, and then surgeons can plan whether to treat with antibiotics, an operation, or, if the infection is spread too far, an amputation.

Slice by slice images

Specially wound coils, known as gradient coils, allow for the detailed depth imaging which creates the slice-by-slice pictures. While the main superconducting magnet creates a very stable magnetic field, these gradient coils create variable magnetic fields during the scan. These fields mean that the magnetic strength within the patient can be altered in specific areas. Since the protons realign at different rates in different tissue types, the relationship between the strength of the field and the frequency of the emitted photons is different for various tissues. Detecting these differences allows for very detailed images.

Powerful computers outside the main machine then reconstitute all of this data to produce slice-by-slice imaging. Depending on what's being scanned, 3D reconstructions can then be created, such as for brain tumours.



5 TOP FACTS MRI SCANNERS

Careful
1 Due to the powerful magnets, any metal objects left in the room can be pulled towards the magnet and can harm patients. Examples have included oxygen cylinders and chairs.

Pacemakers
2 Pacemakers were absolute contraindications to MRI scans. However, modern pacemakers and implantable defibrillators are being designed to be 'MRI safe.'

The most modern
3 MRI scans can be combined with PET scans. These PET-MRI scans produce anatomical and functional images, such as assessing for extent of tumour growth and tumour activity.

Now that's cold
4 The coils of the superconducting magnets are cooled to lower their resistance. Liquid helium cools them to near absolute zero – around -270°C.

Mobile MRI
5 Mobile MRI scanners can go to where the patients are. They are based in big articulated lorries and can be stationed outside hospitals to provide extra scanning capacity.

DID YOU KNOW? *Around ten per cent of patients are too claustrophobic for conventional MRI scanners*

The MRI scanner

It's a big, hi-tech machine and there are different varieties all around the world, found in hospitals, medical research centres and even zoos, but they all work on common principles of manipulating the laws of physics

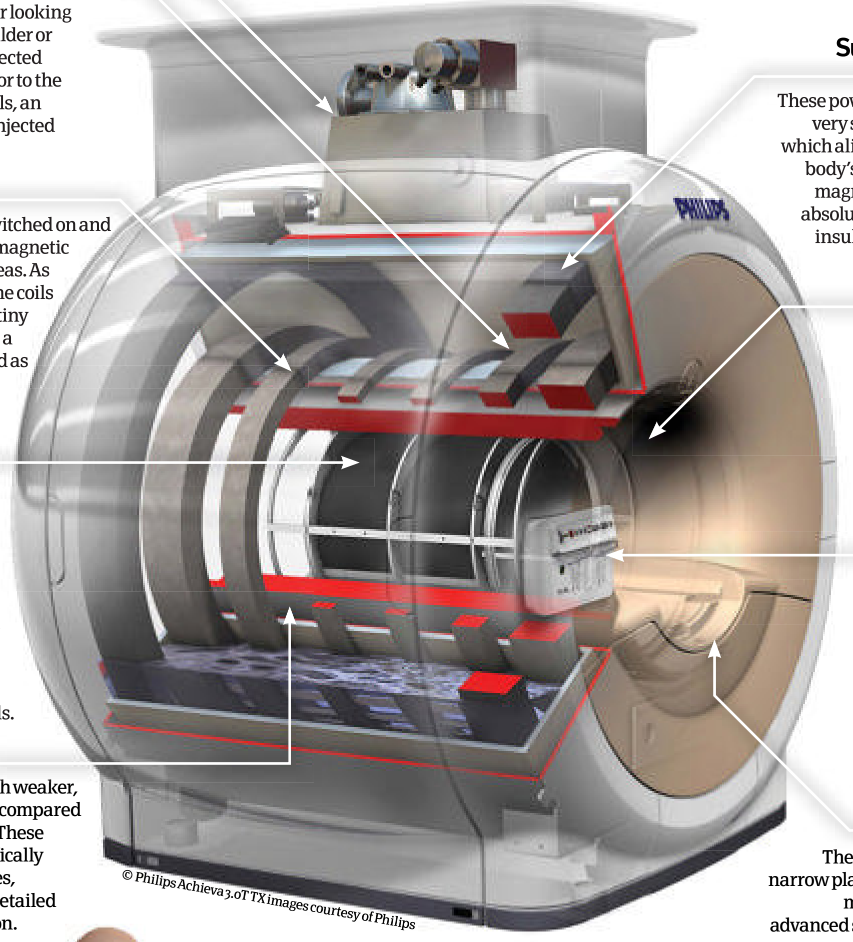
Radiofrequency transmission
A radiofrequency transmission causes the protons to flip around, and then turning this off causes the protons to re-align. This movement releases energy which is detected by the scanner to create pictures.

Enhancement
Contrast agents are used in addition to enhance the contrast between tissue types. For looking at joints such as the shoulder or knee, contrast can be injected directly into the joint prior to the scan. For the blood vessels, an intravenous contrast is injected during the scan.

Bang bang!
The gradient coils are switched on and off rapidly and alter the magnetic field in specific tissue areas. As they switch on and off, the coils contract and expand by tiny amounts – this produces a loud noise which is heard as a series of loud bangs.

Looking for tumours
Since the protons in different tissue types return to their normal state at different rates, they give off different frequencies of energy and so contrast between different types of tissues can be seen. This allows identification of a brain tumour from normal cells.

Gradient coils
These coils produce much weaker, variable magnetic fields compared to the superconductors. These gradient fields are specifically targeted to certain tissues, allowing for depth and detailed tissue type differentiation.



© Philips Achieva3.0T TX images courtesy of Philips

Superconducting magnets
These powerful magnets create very stable magnetic fields, which align protons within the body's hydrogen atoms. The magnets are cooled to near absolute zero and so are well insulated from the patient.

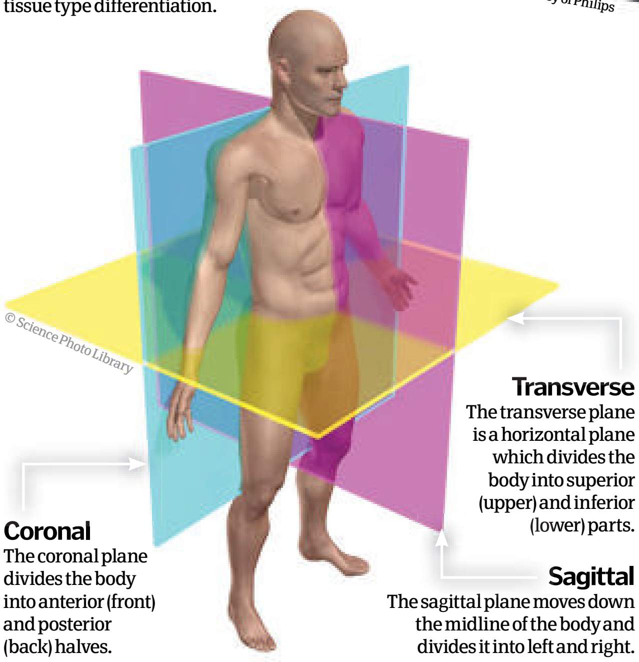
The tunnel
The tunnel in which the patient lies is very narrow; some patients don't fit. There are small lights and a radio with headphones to keep you comfortable.

The computer
Once the changes in energy have been detected within the scanner, they are transmitted to powerful computers outside the scanner, which transform the data into useful images.

Lie here
The patient lies down on a narrow plastic 'table' outside the machine, which is then advanced slowly into the tunnel.

Which direction?

Medical teams need to communicate using the same terms so they are clear what they are looking at. The cross-sectional images produced by MRI scanners are extremely complex, but this is why they are so useful. The terms to the left are the imaginary lines that provide cross-sections. The planes can be moved across the body to look at whole organs or areas.



© Science Photo Library

Transverse
The transverse plane is a horizontal plane which divides the body into superior (upper) and inferior (lower) parts.

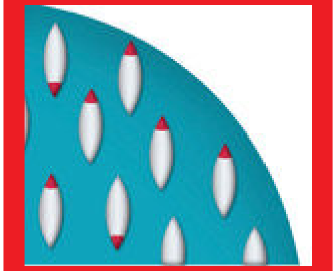
Coronal
The coronal plane divides the body into anterior (front) and posterior (back) halves.

Sagittal
The sagittal plane moves down the midline of the body and divides it into left and right.

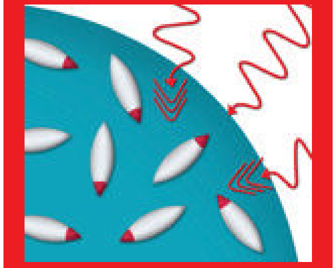
You'll need to be an expert to interpret the imagery

MRI atoms

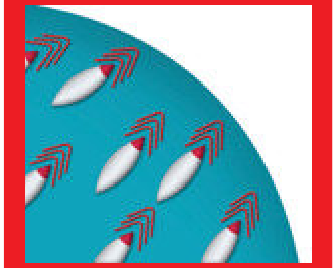
It's a matter of reading the alignment



Line up please
Hydrogen atoms contain just one proton and emit tiny magnetic fields. When placed in a stronger magnetic field (the one produced by the magnets), these protons line up in the direction of the field.



Flip and spin
The scanner emits a radiofrequency through the patient, which flips the spinning direction of these aligned protons. The frequency is at just the right pitch, producing a 'resonance' energy (hence magnetic resonance).



Flip back
Once the radiofrequency is removed, the protons degrade back to their original positions. As they do so, they release tiny amounts of radiowave energy in the form of photons. It is these changes that build the detailed pictures.

Converting to pictures
Different magnetic strengths produce different frequencies in the protons, which are also affected by the different type of body tissues. The resultant energy given off by re-aligning the protons is interpreted by a computer to produce detailed images.

Lift/elevator mechanics

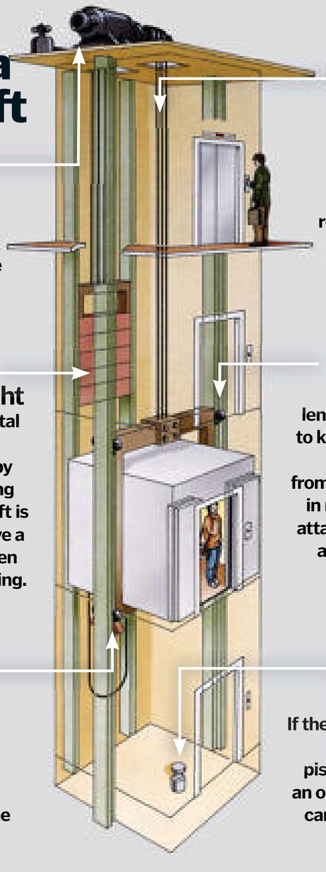
The lift was a world-changing invention because it enabled the creation of today's stunning skyscrapers, not to mention saving an incredible amount of time and effort! Imagine a world with just stairs…

Most modern lifts use a cable system. The lift car runs up and down rails within a shaft, and at the top of the shaft is an electric motor that turns a large wheel, or sheave. Cables run over this, one end of which is attached to the car, the other end to a counterweight.

The counterweight weighs the same as the car plus a typical half load, which means that the two structures balance each other out, so the motor doesn't need to work very hard to move the lift; it just needs to overcome the friction within the system. Of course, the motor must be strong enough to cope with the lift being fully loaded, but this only happens occasionally.

A number of cables are used as back-up in the rare event of one failing. In addition, an automatic brake activates if the lift falls too fast. So those horror-movie scenes of plummeting lifts and flailing cables can never become reality.

Inside a lift shaft



Electric motor This drives the ropes that are looped around the sheave, which is a grooved pulley system.

Cables In cable-based lifts, the car is raised and lowered by traction steel ropes. Most lifts have between four and eight cables.

Counterweight A collection of metal weights that help conserve energy by adding accelerating power when the lift is ascending but have a braking effect when the lift is descending.

Guide rails These run the length of the shaft to keep the car and counterweight from swaying when in motion. Rollers attached to the car also keep transit smooth.

Braking system Some lifts have electromagnetic brakes that are activated automatically if the lift loses power.

Shock absorber If the brakes fail and the car falls, a piston mounted in an oil-filled cylinder can save lives as a last resort.

How circular saws work

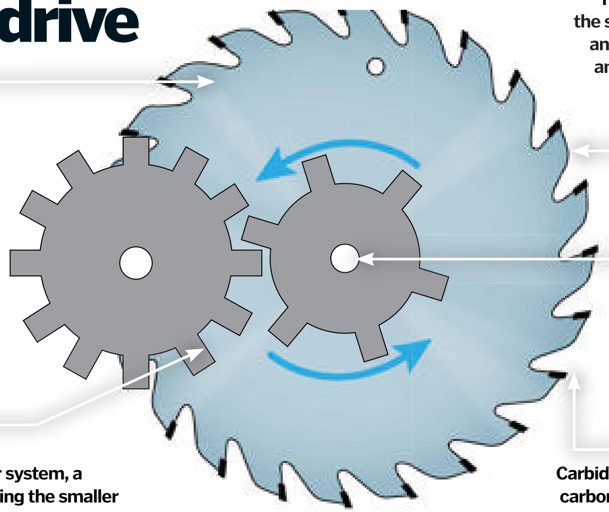
Using a torque force, these clever cutting tools make light work of wood

Circular saws rely on providing a large 'torque' in the centre of a hole in the blade.

As a force is applied to one side of the hole, a torque force is created much like when using a spanner on a nut, although significantly faster. When cutting through an object such as wood, the circular saw is placed flat with the saw pointing down. The wood is clamped in place. By slowly moving the blade through the wood it will produce a clean cut.

There are several types of circular saw, most spinning at up to 3,500 rotations per minute (rpm) to make a clean cut through an object. Some connect the motor directly to the saw for a one-to-one speed ratio. Others use a combination of large and small cogs to alter the revolution of the saw and ultimately the speed. For example, by attaching a large gear cog to a smaller one on the blade, usually at a ratio of two to one, a motor turning at 1,750 rpm will actually move the blade at 3,500 rpm.

Double gear drive



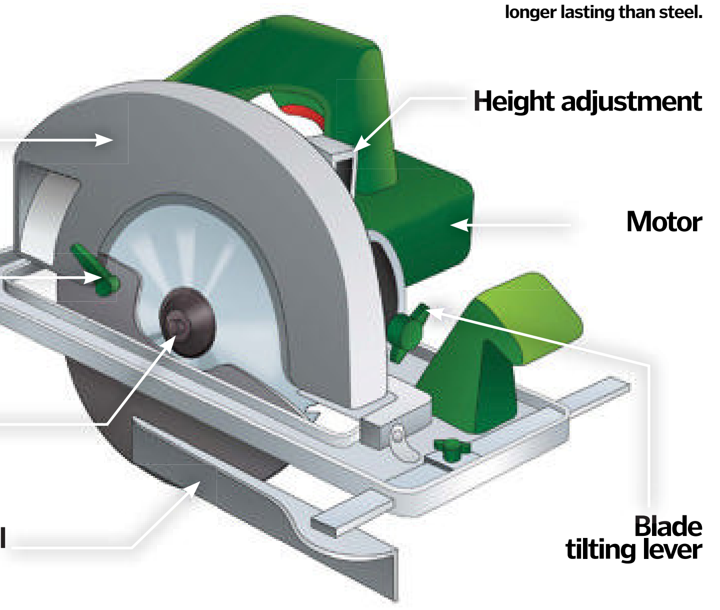
Gullet The teeth are designed to remove any material shed from the object it is cutting. This allows for a clean cut with no rough edges.

Teeth For each revolution, the saw will cut further and more swiftly into an object if there are more teeth.

Blade hole Although most saws use a round hole, some use a diamond shaped hole for a higher torque force.

Double gear In this double gear system, a large cog is powering the smaller cog by applying a large torque force, which increases the number of revolutions.

Tip Carbide is a compound of carbon and iron, which is sometimes used to make the teeth. It is stronger and longer lasting than steel.

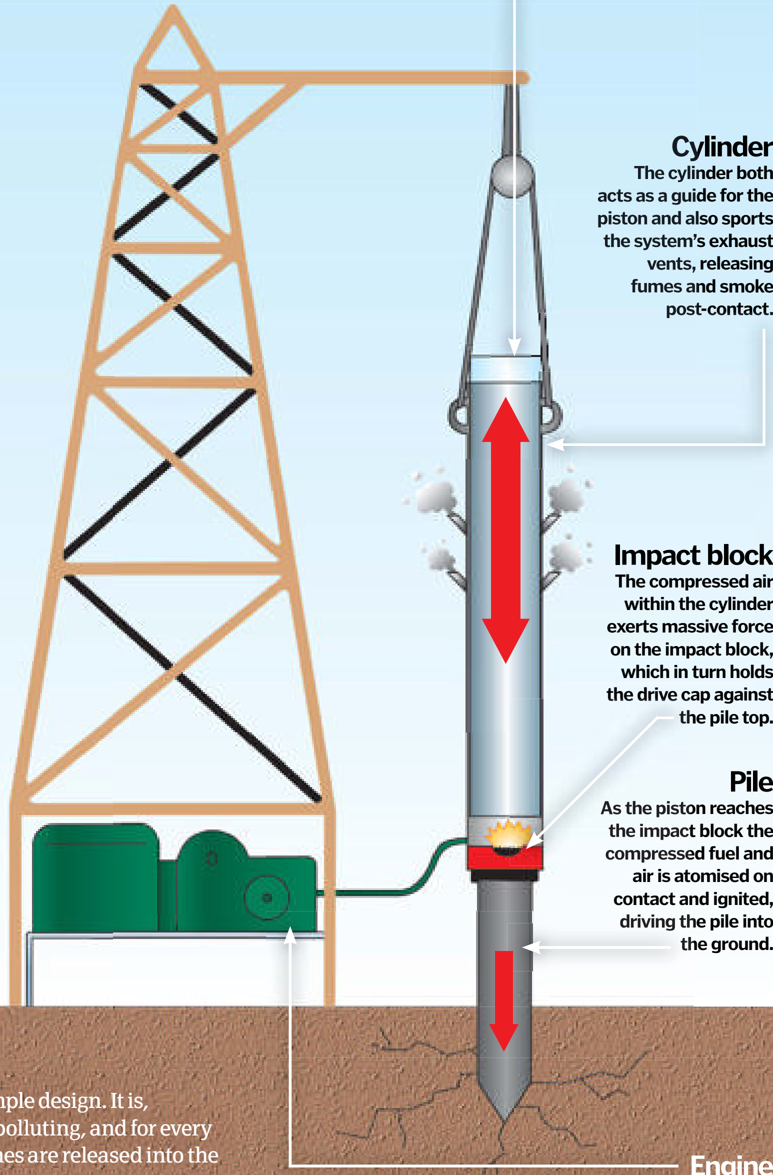


Pile drivers

How do these mechanical monsters puncture holes in the Earth?

Most pile drivers are mounted on trucks

A pile driver being used for bridge building in California



Piston
Once released, the piston, which is also a massive weight, free-falls within the cylinder compressing air and fuel added by a fuel pump within.

Cylinder
The cylinder both acts as a guide for the piston and also sports the system's exhaust vents, releasing fumes and smoke post-contact.

Impact block
The compressed air within the cylinder exerts massive force on the impact block, which in turn holds the drive cap against the pile top.

Pile
As the piston reaches the impact block the compressed fuel and air is atomised on contact and ignited, driving the pile into the ground.

Engine
Often a large two-stroke machine, the diesel engine lifts the piston/weight to the top of the support structure.

A pile driver is a mechanical device used to drive piles – deep-lying structural foundations – into the Earth. Traditionally, pile drivers worked by suspending a large heavy object above the pile needing to be driven into the Earth within a guidance frame, which was then released to freefall upon it before being winched back up for another freefall. Modern pile drivers, however, have evolved and come in three types: diesel hammer, hydraulic hammer and vibratory hammers.

Diesel pile drivers operate by utilising a piston in conjunction with a cylinder to compress air and fuel on top of an impact block. Due to the resulting contained explosion once ignited, this has the dual effect of driving the below pile into the ground and projecting the above piston back to the top of its housing, ready to fall again under gravity for another drive cycle. This type of pile driver is the most common worldwide as it is relatively cheap to operate and features a deceptively simple design. It is, however, the most noisy and polluting, and for every cycle, smoke and exhaust fumes are released into the atmosphere post-drive.

Hydraulic drivers are newer than diesel variants and employ cylinders stocked with hydraulic fluid where traditionally compressed air and fuel would be used to generate the system's driving force. These systems are often preferred now in construction as they mitigate the effects of vibration on the pile and surrounding areas, something especially important in built-up areas where other structures may potentially be compromised. Typically, hydraulic pile drivers work within 70 decibels too, which also makes them considerably quieter in operation than diesel or vibration drivers.

Vibration pile drivers work differently to diesel and hydraulic variants, utilising a series of hydraulically powered, counter-rotating eccentric weights designed to cancel out generated horizontal vibrations, but transmit vertical ones into the below pile, hammering it into the ground. Due to the reduced need for vertical piston clearance on this type of driver they are often used in situations when space is at a premium – for example when adding additional supports to an existing bridge. Depending on the hardness of the Earth, various hammers can be fitted to these pile drivers, ranging from those that perform 1,200 vibrations per minute, all the way up to 2,400.

Oblivion is one of Alton Towers' main attractions

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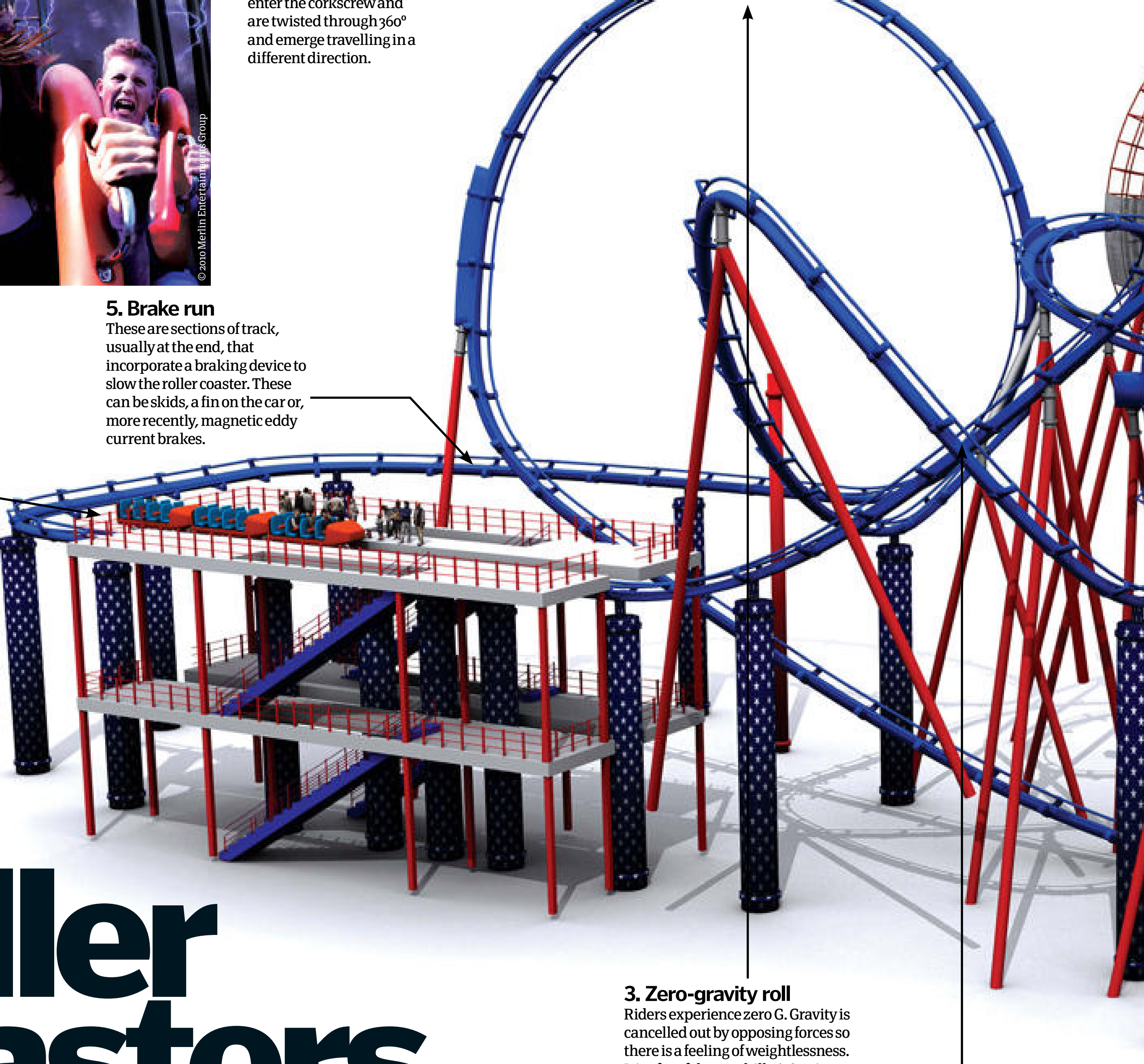


1. Corkscrew
The corkscrew is among the most famous roller coaster elements. Trains enter the corkscrew and are twisted through 360° and emerge travelling in a different direction.

6. Train
Two or more cars linked up are called a train. The position of the car in a train dictates the effects on the riders.

5. Brake run
These are sections of track, usually at the end, that incorporate a braking device to slow the roller coaster. These can be skids, a fin on the car or, more recently, magnetic eddy current brakes.

3. Zero-gravity roll
Riders experience zero G. Gravity is cancelled out by opposing forces so there is a feeling of weightlessness. It is often felt on uphill 360° twists.

7. Dive loop
A dive loop is a type of roller coaster inversion where the track twists upwards and to the side, and then dives toward the ground in a half-vertical loop

Roller coasters

They strike fear into many, but we still love them! Here, we detail the engineering achievement that is the roller coaster

Some of the world's most forward-looking engineering is actually in operation right now, in the unexpected setting of the world's theme parks. From the pioneering 18th Century 'Russian Mountains', people have been hooked on the frightful thrill of a roller coaster – and ever since, the challenge has been to make an even bigger, even better, even more terrifying one.

Today, they incorporate solutions that are at the leading edge of scientific development. This means they are able to accelerate as fast as a drag racer and let passengers experience G-forces way in excess of a Formula 1 race car.

They do all this in complete safety, having passed the very strictest engineering standards. People travel for miles to ride on the latest roller coaster – they'll even cross continents just to experience the latest thrill. But why? Here, we explain all…

5 TOP FACTS
MOST THRILLING ROLLER COASTERS

Ferrari World, Abu Dhabi

1 Opened in 2010, Ferrari World is home to the world's fastest roller coaster. Formula Rossa has a top speed of nearly 240km/h (150mph) and riders have to wear safety goggles.

Kingda Ka, New Jersey

2 This 'Strata coaster' is not only the tallest (139m/456ft), it also has the biggest drop (127m/418ft), and before Formula Rossa opened it was also the fastest in operation.

Steel Dragon 2000, Nagashima, Japan

3 For sheer length of thrill, this one tops the lot with a running length of 2,479m (8,133ft). Hopefully you won't decide you hate it after the first twist.

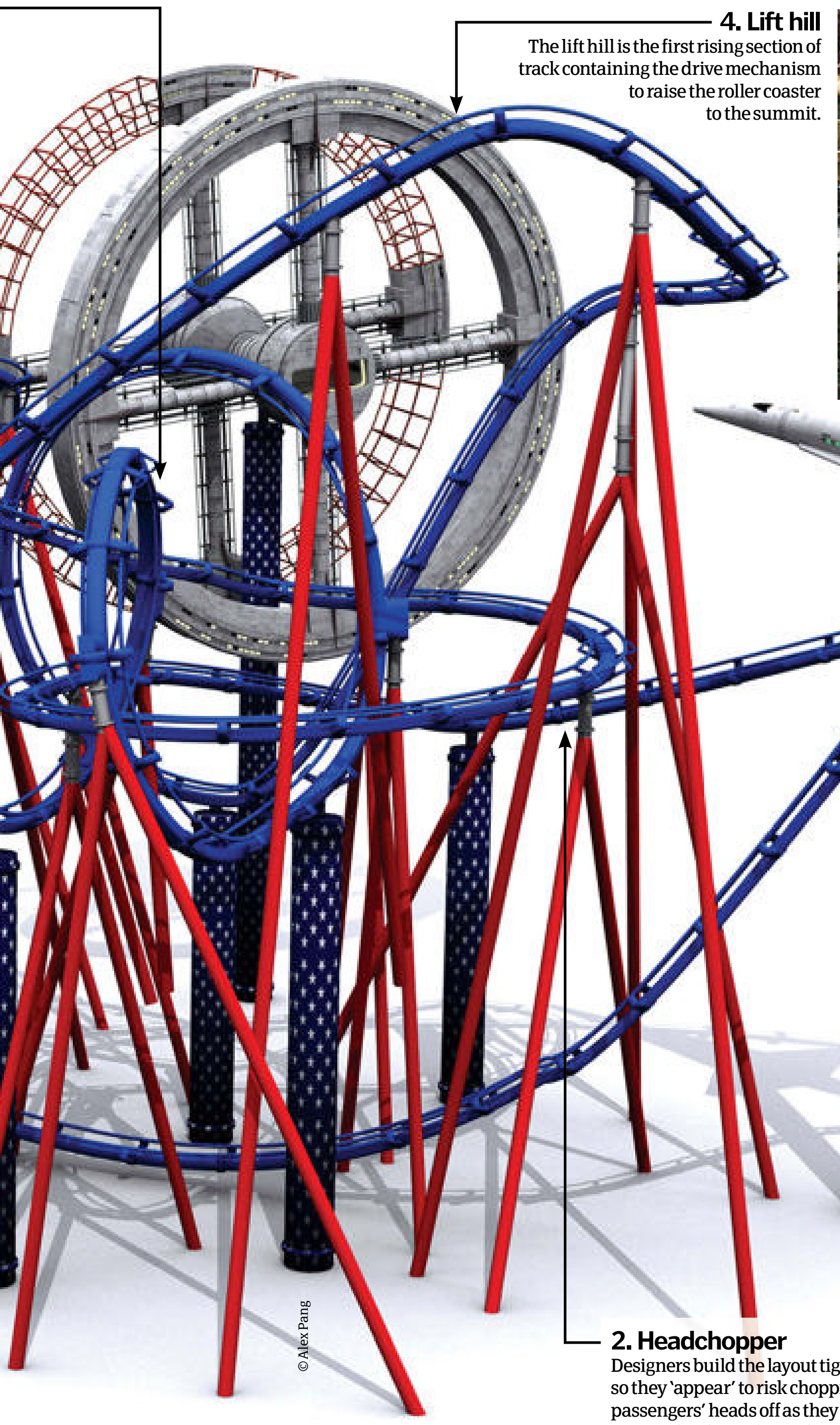
Colossus, Thorpe Park, UK

4 A combination of loop, double corkscrew, heartline roll, cobra roll and quad heartline roll hand this ride has a record number of inversions.

Ring Racer, Nurburgring, Germany

5 Running parallel to the famed German racetrack, this goes from 0-217km/h (0-135mph) in 2.5 seconds! That's way beyond any road car.

DID YOU KNOW? *American LaMarcus Adna Thompson is considered the 'father of the roller coaster'*



4. Lift hill
The lift hill is the first rising section of track containing the drive mechanism to raise the roller coaster to the summit.

2. Headchopper
Designers build the layout tightly so they 'appear' to risk chopping passengers' heads off as they approach! The reality is there's ample clearance, but it's a big part of the thrill.

© Alex Pang

Smile for the camera…

© Photo Merlin Entertainments Group

How roller coasters roll

Roller coaster trains are unpowered. They rely on an initial application of acceleration force, then combine stored potential energy and gravitational forces to continue along the track. This is why they rise and fall as they twist and turn.

There are various methods of launching a roller coaster. Traditionally, a lift hill is used – the train is pulled up a steep section of track. It is released at the top, where gravity transfers potential energy into kinetic energy, accelerating the train. Launches can be via a chain lift that locks onto the underneath of the train, or a motorised drive tyre system, or a simple cable lift. There is also the catapult launch lift: the train is accelerated very fast by an engine or a dropped weight.

Newer roller coasters use motors for launching. These generate intense acceleration on a flat section of track. Linear induction motors use electromagnetic force to pull the train along the track. They are very controllable with modern electronics. Some rides now have induction motors at points along the track, negating the need to store all the energy at the lift hill – giving designers more opportunities to create new sensations. Hydraulic launch systems are also starting to become more popular.

Careful calculation means a roller coaster releases roughly enough energy to complete the course. At the end, a brake run halts the train – this compensates for different velocities caused by varying forces due to changing passenger loads.

Anatomy of a roller coaster

Roller coasters comprise many elements, each with its own specific physical characteristics. Designers give a ride character by applying an understanding of physics to build up a sequence of thrills. These are all interrelated and mean the experience of every ride is exciting and unique.

Computer models can analyse the forces that will be produced by each twist and turn, ensuring they are kept within specific boundaries. Roller coasters may look like a random snake of track, but the reality is years of scientific calculations to provide just the right effects.

The Stealth ride at Thorpe Park isn't for the faint-hearted

© Photo Merlin Entertainments Group

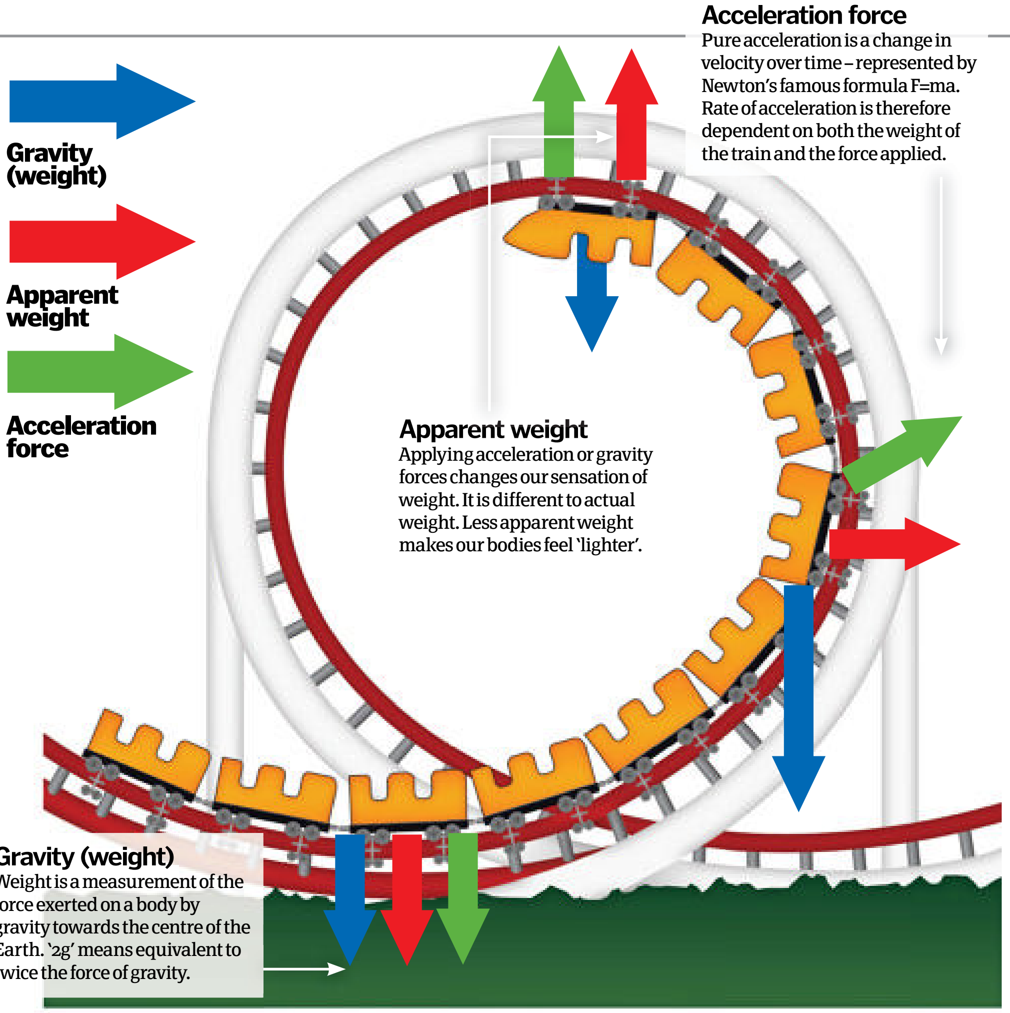
The physics of the ride

The science that gets roller coasters going

All roller coasters begin with an acceleration force. This is to overcome inertia – the resistance to change in velocity. It is quantified by the mass of the train, which depends on the individual load. Full trains will have more inertia than unladen ones. However, by applying more force during acceleration, they also store more potential energy to offset this. Designers work to reduce other sources of inertia such as friction-reducing low rolling resistance wheels.

The aim of acceleration is to store sufficient potential energy at the top of the crest for transferral into driving kinetic energy to take the train to the next ascent. Because of frictional and other losses, each subsequent incline will be shorter than the one before – not all the kinetic energy can be recovered into potential energy.

Gravity is fundamental to roller coasters. Designers manipulate the effect of attraction between two masses to subject strong forces on the body. Weightlessness, for example, is caused by centrifugal forces cancelling out gravity forces. Centrifugal force feels like an outward force away from the centre of rotation when turning a corner. It's as if the body is being pressed down into the train, but is actually the reverse: an external force is being supplied by the train towards the centre of rotation.



Acceleration force
Pure acceleration is a change in velocity over time – represented by Newton's famous formula F=ma. Rate of acceleration is therefore dependent on both the weight of the train and the force applied.

Apparent weight
Applying acceleration or gravity forces changes our sensation of weight. It is different to actual weight. Less apparent weight makes our bodies feel 'lighter'.

Gravity (weight)
Weight is a measurement of the force exerted on a body by gravity towards the centre of the Earth. '2g' means equivalent to twice the force of gravity.

Need for speed
The roller coaster is accelerated to the ground faster than gravity – this causes negative G-force that presses you back into the seat.

© 2010 Merlin Entertainments Group.

G makes it great

The aim of a roller coaster is to subject forces on the body people do not normally experience. These have to be within safe medical limits, and to do this designers consider physiology. The body is more capable of tolerating vertical forces than horizontal ones. This is particularly the case for compression forces. Many roller coasters therefore compress passengers firmly into their seats, with forces up to +6g, but won't let them 'float' out too severely – the effects of a negative 2g force will still be strongly felt!

An intolerance of side forces is why many roller coaster corners are banked. This reduces the G-forces on passengers to around 1.5g, helping protect necks. It is unable to deal with high side forces so careful consideration must be given here to not injure people.

Overall, though, a roller coaster is the only thing this side of a race car or space shuttle where you can feel what such incredible forces are like. Are your body and your constitution up to it?

Summit approach
The approach to a summit appears to be about to launch you into the air as no track is visible in front!

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Loop
Serious G-force is felt during the loop, along with disorientation as the track disappears over your head.

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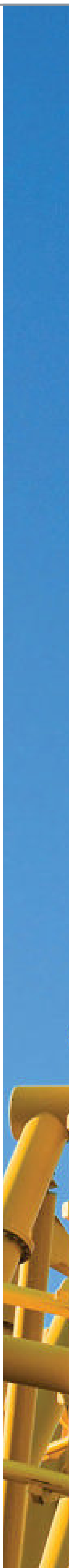

THE STATS ROLLER COASTERS

FASTEST 240km/h TALLEST 139m LONGEST 2,479m BIGGEST DROP 127m MOST INVERSIONS 10 DROP ANGLE 97

DID YOU KNOW? *A human intolerance to side forces is why many corners and bends are banked*

Train to retain

Keeping you on the right track

Roller coaster trains themselves are quite simple – they are not powered so do not have to account for drive mechanisms. They do, however, have to incorporate a method of picking up drive from the roller coaster itself – either through connection to a launch track or chain lift, or via power from induction motors.

There is much redundancy built into the connection between train and track. There are a series of wheels which run on the sides and underneath of the track as well as the usual top-running wheels. Side wheels drive it and wheels below stop it moving up off the track. The top wheels carry the load of the passengers. In combination, the wheels lock the train securely on the track.

Train carriages are connected by a flexible joint that securely attaches despite the extreme angles, twists and turns that can occur between the two trains. Carriages themselves are usually steel structures, with classic roller coasters using wooden trains.

Chessington

Side wheels
Wheels to the side and wheels below prevent the train from being derailed.

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THORPE PARK

Top wheels
The wheels above the track support the weight of the passengers.

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Belts for the fans

Two types of restraint are common – lap bars and over-shoulder restraints. Older roller coasters use lap bars – floor-mounted padded bars that swing down above the passenger's legs and lock at either side of the carriage. This double locking means if one side fails, the other will still restrain people. Roller coaster connoisseurs like them for the greater freedom but they are not as safe.

Most roller coasters now use over-shoulder bars. These are U-shaped padded bars that swing down to lock over the passengers' shoulders. They hold securely and also mean occupants cannot fly out of their seat: an essential for inversion rides. Secondary strap belts are often fitted too – for redundancy, and for measurement: they're sized to fit the largest possible person, no larger!

Learn more

The Roller Coaster Database is a great source of top stats (**http://rcdb.com/**). Fan sites include Ultimate Roller Coaster (**http://www.ultimateroller coaster.com/**) and ThrillNetwork (**http://www.thrillnetwork.com/**). Discovery also airs special programmes on roller coasters and has a great roller coaster builder resource on its website (**http://dsc.discovery.com/games/coasters/interactive.html**). The industry body's IAAPA (**http://www.iaapa.org/**) and BlooLoop (**http://www.blooloop.com/index.aspx**) provide news for the theme park industry.

Feeling hot?
The twists of Thorpe Park's Nemesis Inferno demand over-the-shoulder restraints.

© 2010 Merlin Entertainments Group

Hold on tight
Colossus is the UK's only quadruple corkscrew.

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Drilling for oil offshore

The world produces over 82 million barrels of oil every day, much of it in harsh conditions, miles from shore and safety in the event of an emergency. So how is it done?

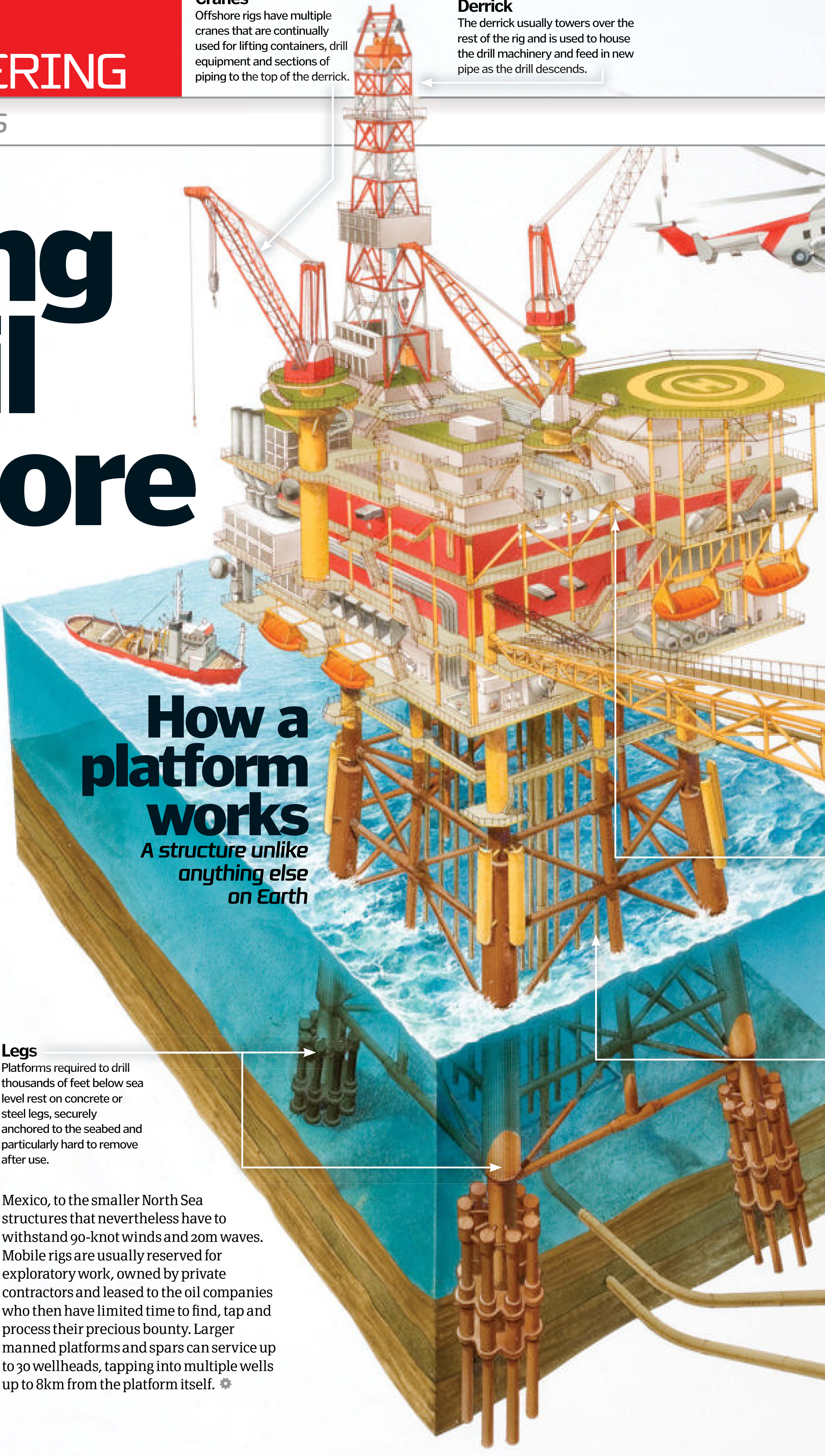
Oil has been around for millions of years, located deep below the land or sea where it became trapped under layers of permeable rocks, or slowly seeping to the surface. Although examples of oil drilling were documented in 4th Century China, the first modern oil-gathering structure was built in 1897, and by 1928 mobile rigs consisting of a simple barge with a drill mounted on top had set the scene for a revolution that fuelled Western industrial dominance for the next century.

Over 82 million barrels of oil are produced every single day, a process that usually starts with a range of surveys. These include geographical and geomagnetic surveys and the deep echo sounding or seismic reflection surveys that pinpoint the likely location of a substantial deposit. Only then – and after the necessary permits have been obtained – can the rigs move in. These multi million-pound structures are positioned by teams of professionals who make the well safe and drill down to its precious commodity.

Today, there are over 40,000 oil fields around the world, with most offshore drilling undertaken in the Continental shelf – the sunken perimeter of a continent's original glacial shape. From the $100 million monsters that plumb the deepest waters in the Gulf of Mexico, to the smaller North Sea structures that nevertheless have to withstand 90-knot winds and 20m waves. Mobile rigs are usually reserved for exploratory work, owned by private contractors and leased to the oil companies who then have limited time to find, tap and process their precious bounty. Larger manned platforms and spars can service up to 30 wellheads, tapping into multiple wells up to 8km from the platform itself.

How a platform works

A structure unlike anything else on Earth



Cranes
Offshore rigs have multiple cranes that are continually used for lifting containers, drill equipment and sections of piping to the top of the derrick.

Derrick
The derrick usually towers over the rest of the rig and is used to house the drill machinery and feed in new pipe as the drill descends.

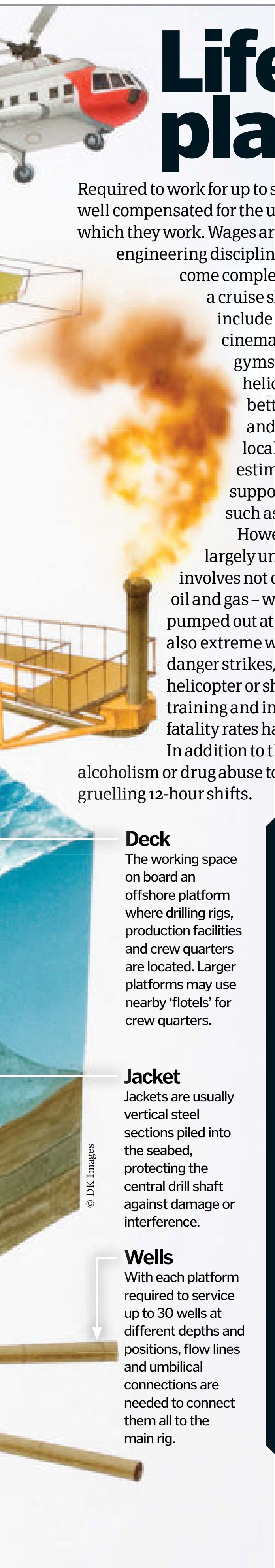
Legs
Platforms required to drill thousands of feet below sea level rest on concrete or steel legs, securely anchored to the seabed and particularly hard to remove after use.

DID YOU KNOW? As North Sea reserves run dry, the estimated cost of removing the structures would exceed £621 billion

Life on a platform

Required to work for up to six months a year, oil workers are well compensated for the undeniably hazardous conditions in which they work. Wages are typically higher than in similar engineering disciplines and the larger platforms and spars come complete with facilities more appropriate to a cruise ship than a floating factory. These can include private rooms for the 100+ crew, cinemas, 24-hour restaurants and even gyms. Supplies are usually brought in by helicopter or ship, making oil platforms better stocked than most workplaces and significantly more important to the local economies in which they reside. It is estimated that every offshore worker supports up to ten more in local industries such as food, transport or maintenance.

However, the dangers are constant and largely unpredictable. Offshore drilling involves not only dealing with highly flammable oil and gas – with the added danger of this being pumped out at exceptionally high pressures – but also extreme wind and sea conditions. When danger strikes, support is often miles away by helicopter or ship, and despite the high levels of training and increasingly safe equipment, offshore fatality rates have been on the rise in recent years. In addition to this, workers are often prone to alcoholism or drug abuse to overcome the isolation and gruelling 12-hour shifts.


Deck
The working space on board an offshore platform where drilling rigs, production facilities and crew quarters are located. Larger platforms may use nearby 'flotels' for crew quarters.
Jacket
Jackets are usually vertical steel sections piled into the seabed, protecting the central drill shaft against damage or interference.
Wells
With each platform required to service up to 30 wells at different depths and positions, flow lines and umbilical connections are needed to connect them all to the main rig.

© DK Images

Above: Accommodation decks of a North Sea oil platform
Below: A worker checks the drilling head on a tower

Oil rig teamwork

A small selection of the different roles on a rig…

Offshore installation manager

Also known as the Man in Charge (MIC) the installation manager makes all key production decisions, both before, during and after drilling. He has usually worked his way through the other drill team roles.

Driller

A highly specialist discipline, the drillers are those who operate the drilling equipment, including making the initial hole in the seabed. The driller is effectively in charge of everything that happens on the rig floor.

Derrickman

So called because of their position at the top of the derrick, derrickmen are usually working roughnecks responsible for guiding the pipe into the drill as well as operating mud pumps and other such machinery.

Roughneck

The grunts of the oil business, roughnecks work in teams of three and are mainly responsible for manual work both during and after drilling. They can also be called on to operate other equipment such as mud shakers.

Tool pusher

On an offshore rig, tool pushers tend to be department heads in charge of drilling or other essential functions such as engineering or operations. They may also assist with administrative work, such as payroll or benefits.

THE RIGHT RIG FOR THE JOB

Drill Ships

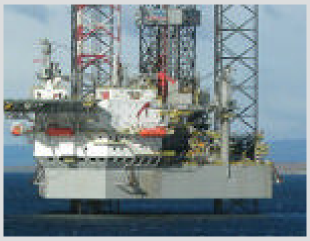
Designed for speculative or deep-water mining, these vessels are converted to include a drilling platform in the centre. Drill ships use sophisticated sensors and satellite tracking to keep them moving while lined up to the well.

Semi-submersibles

Made up of floating pontoons and columns able to sink in the water where they are anchored to the sea floor or kept in place by steerable thrusters. Effective at drill depths of up to 1,800m, they're designed for quick deployment.

Jack-up

Mobile platforms can be raised above the sea on extendable steel legs. Designed for depths of 500m or less, they are useful for small to mid-sized deposits and typically only support smaller crews.

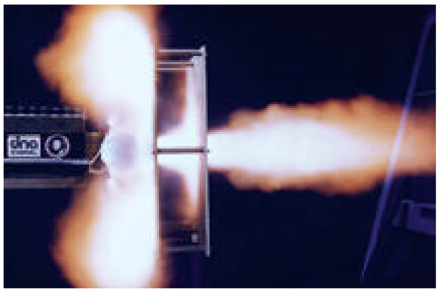


Rig

An immovable structure of concrete and steel that rests on the seabed with deck space for multiple rigs, crew quarters and production facilities. Their design and expense makes them appropriate for larger offshore deposits.

Spar

Perfect for major oil fields, such as the North Sea, spars are drilling platforms fixed to giant, hollow hulls that can descend up to 250m, still above the ocean floor and secured by cables.



It could still be years before we see railguns used in combat

The fire power of a railgun

The US Navy have test-fired a railgun that fired a projectile at 2,520mps

Electricity is the secret behind high-tech railguns

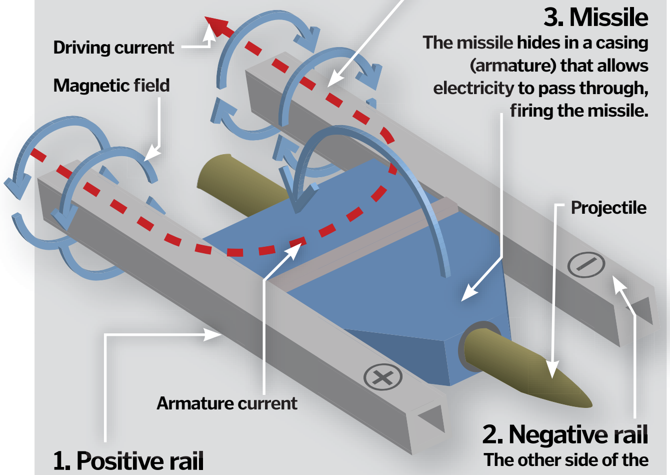
For many centuries gunpowder was the explosive propellant of choice in warfare, partly because there was little else to actually choose from. However, inevitably modern technology has evolved, and so too did the gun and its ammunition. Careful experiments in the early-20th Century made way for anti-aircraft cannons that harnessed the intense power of electricity, and soon after the railgun was born.

A railgun consists of two conductive rails (also known as bars), electrical current, and a projectile, such as a rocket or missile. The two rails sandwich the conductive projectile, which is itself encased inside a shell to make for a complete electrical circuit. Apart from nearly overheating and melting due to the immense amount of friction inside the gun created every time it's fired, a railgun is a truly groundbreaking step from its former ally: gunpowder.

Ammunition in a railgun is propelled with the help of magnetism. As the electrical current flows through one of the rails, it passes through the projectile and onto the opposite rail. One of the rails becomes positively charged and the other becomes negatively charged. This rapidly heating mechanism naturally creates an electromagnetic field. This swirls around both rails holding the projectile, forming an overwhelming power. As the two rails are carrying electrical current in opposite directions the projectile is eventually forced away from the ends of the rails and out of the barrel. The speed all depends on how much current is used and the length of both rails, but can be up to ten times faster than a weapon using gunpowder.

The materials for a railgun have to be highly heat resistant, and they are built to withstand extreme opposing forces made when the projectile is fired. It's also worth considering that the cost of electricity used to power a single railgun is colossal but could be greatly offset as the cost of otherwise-lost bullets is reduced.

Firing the railgun



4. Electricity
The source of the electricity is mounted with the railgun to pump current.

3. Missile
The missile hides in a casing (armature) that allows electricity to pass through, firing the missile.

1. Positive rail
The positive electrically charged rail holds one side of the missile, creating an electromagnetic field.

2. Negative rail
The other side of the missile is secured by a negative, electrically charged rail.

5 TOP FACTS CRANES

Mobile crane

1 The most versatile crane for both small and large jobs is simply a telescoping hydraulic boom attached to the bed of a heavy-duty construction vehicle.

Overhead crane

2 Shaped like an upside down 'U', this small but powerful crane rolls along tracks on factory floors to lift car engines and other heavy parts into place.

Self-erecting cranes

3 This crane rolls onto the work site as a compact, foldable unit only 13.6m long. The crane rises and extends its jib 32m out with a holding capacity of 4,000kg.

Luffing tower crane

4 The jib arm of this tower crane – which can still carry 35 tons – can be raised from a flat horizontal position to an 85-degree angle using a special jib cable and motor.

Hammerhead tower crane

5 The classic T-shaped tower crane with a fixed horizontal jib and counterweight arm. The hammerhead lacks freedom of movement, but can carry more weight.

DID YOU KNOW? *Tower cranes are designed to withstand wind gusts up to 150km/h*

Load and stability

Hold a 10kg weight close to your body. Now try to extend your arms without tipping over. Tough, isn't it? Tower cranes have the same problem. A large tower crane can handle loads up to 16 tons, but that's only at a horizontal distance that's very close to the tower. At 80 metres out on the jib, the most that the same crane can carry is 3.9 tons. Tower cranes are preloaded with multiple slabs of concrete counterweights to maintain the overall equilibrium of the arm. A crane that carries heavy loads at 80 metres from the tower requires 31 tons of counterweight.

How tower cranes work

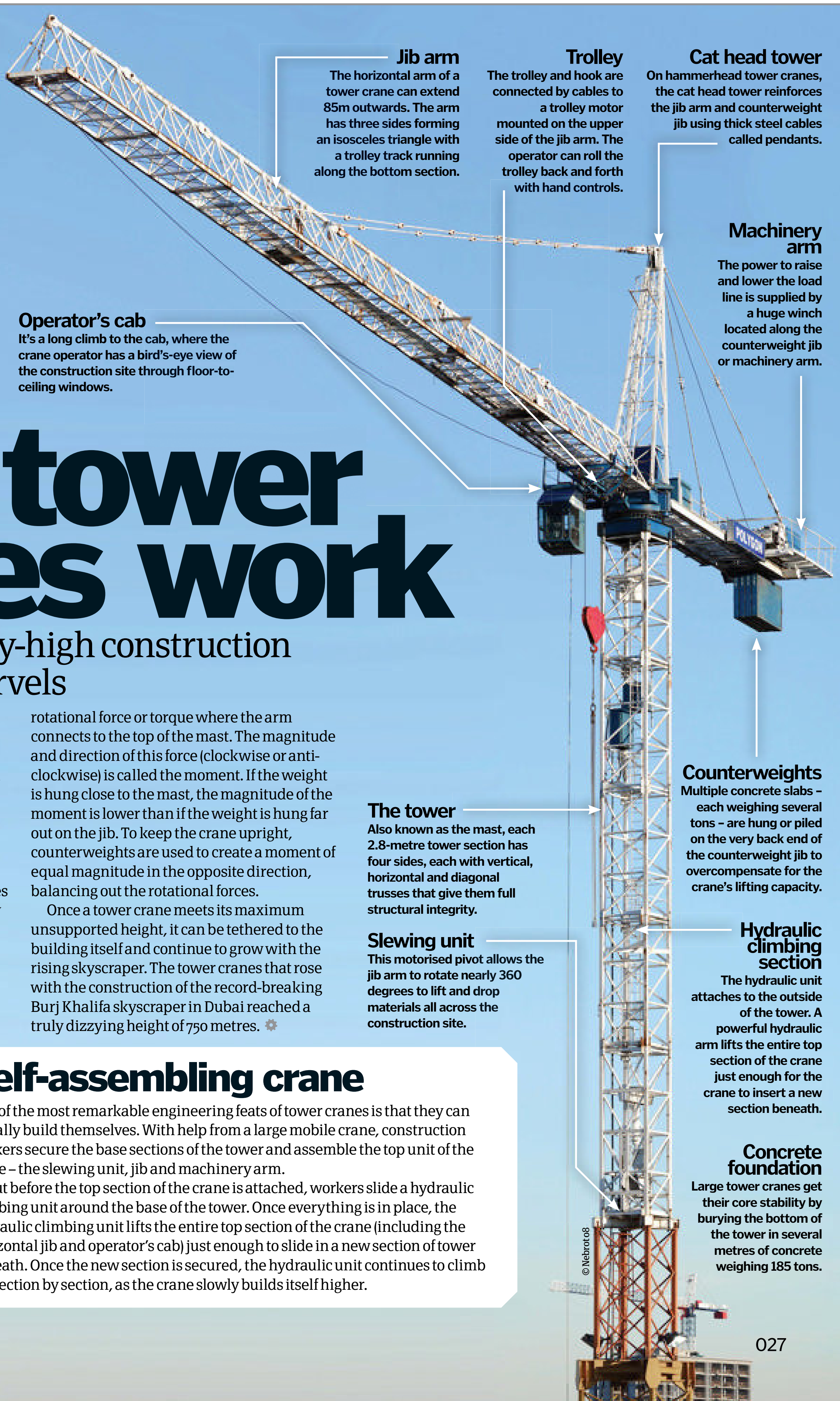
These big birds of sky-high construction are engineering marvels

Tower cranes flock to money. During the economic boom years, high-rise construction cranes migrated from Beijing to Shanghai to Dubai, where it was estimated in 2006 that there was one tower crane for every 44 residents of the desert boom-opolis.

Tower cranes are feats of structural engineering that often outshine their creations. They are designed to stand 80 metres tall and reach 80 metres out supported only by a narrow steel-frame mast, a concrete foundation and several counterweights.

The engineering principle that keeps the twiggy tower crane from tipping over is something called a 'moment'. If you hang a weight from the crane's jib arm, it exerts a rotational force or torque where the arm connects to the top of the mast. The magnitude and direction of this force (clockwise or anti-clockwise) is called the moment. If the weight is hung close to the mast, the magnitude of the moment is lower than if the weight is hung far out on the jib. To keep the crane upright, counterweights are used to create a moment of equal magnitude in the opposite direction, balancing out the rotational forces.

Once a tower crane meets its maximum unsupported height, it can be tethered to the building itself and continue to grow with the rising skyscraper. The tower cranes that rose with the construction of the record-breaking Burj Khalifa skyscraper in Dubai reached a truly dizzying height of 750 metres. ✲



Jib arm The horizontal arm of a tower crane can extend 85m outwards. The arm has three sides forming an isosceles triangle with a trolley track running along the bottom section.

Trolley The trolley and hook are connected by cables to a trolley motor mounted on the upper side of the jib arm. The operator can roll the trolley back and forth with hand controls.

Cat head tower On hammerhead tower cranes, the cat head tower reinforces the jib arm and counterweight jib using thick steel cables called pendants.

Machinery arm The power to raise and lower the load line is supplied by a huge winch located along the counterweight jib or machinery arm.

Operator's cab It's a long climb to the cab, where the crane operator has a bird's-eye view of the construction site through floor-to-ceiling windows.

The tower Also known as the mast, each 2.8-metre tower section has four sides, each with vertical, horizontal and diagonal trusses that give them full structural integrity.

Counterweights Multiple concrete slabs – each weighing several tons – are hung or piled on the very back end of the counterweight jib to overcompensate for the crane's lifting capacity.

Slewing unit This motorised pivot allows the jib arm to rotate nearly 360 degrees to lift and drop materials all across the construction site.

Hydraulic climbing section The hydraulic unit attaches to the outside of the tower. A powerful hydraulic arm lifts the entire top section of the crane just enough for the crane to insert a new section beneath.

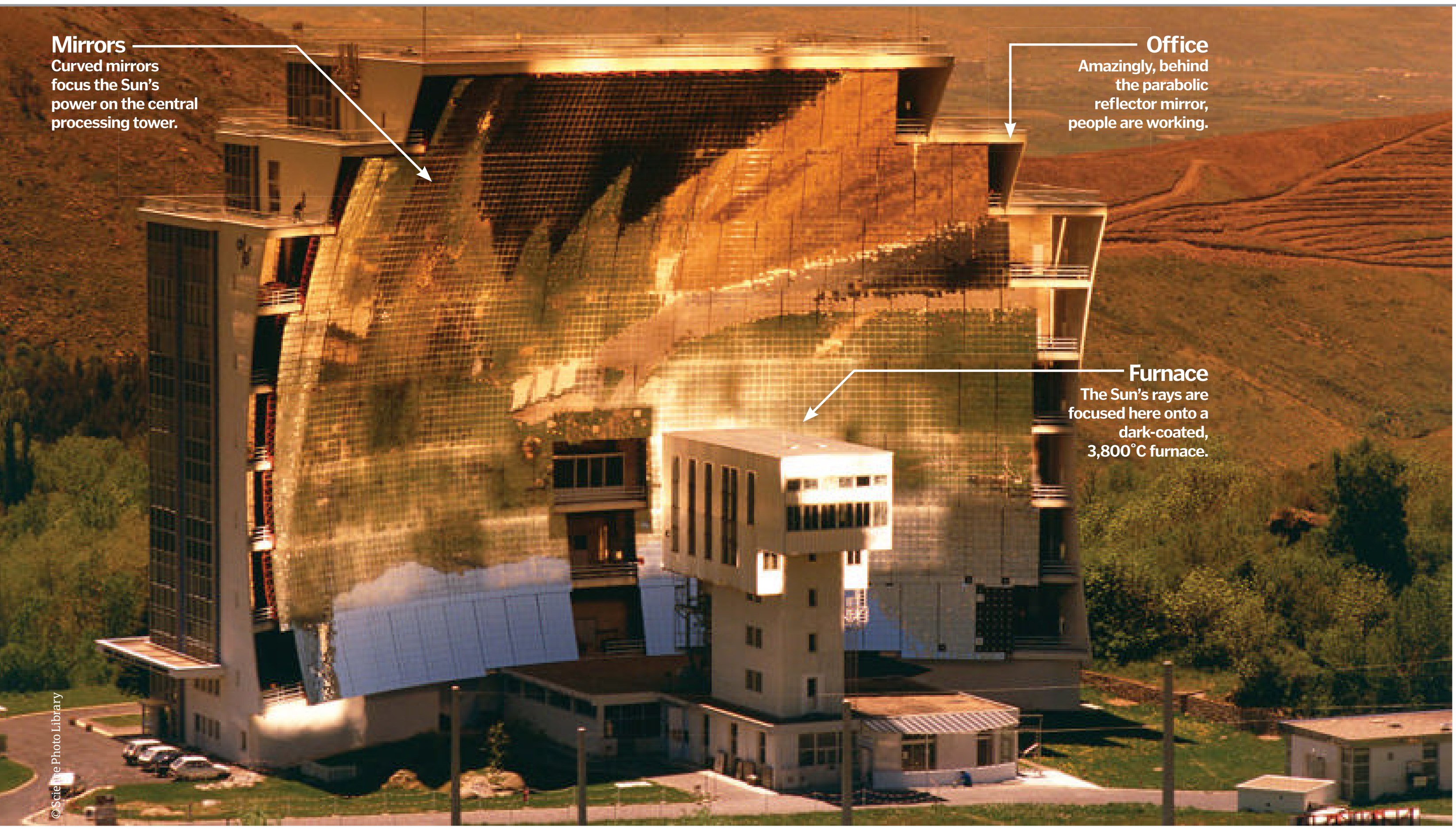
Concrete foundation Large tower cranes get their core stability by burying the bottom of the tower in several metres of concrete weighing 185 tons.

© Nebrot08

Self-assembling crane

One of the most remarkable engineering feats of tower cranes is that they can literally build themselves. With help from a large mobile crane, construction workers secure the base sections of the tower and assemble the top unit of the crane – the slewing unit, jib and machinery arm.

But before the top section of the crane is attached, workers slide a hydraulic climbing unit around the base of the tower. Once everything is in place, the hydraulic climbing unit lifts the entire top section of the crane (including the horizontal jib and operator's cab) just enough to slide in a new section of tower beneath. Once the new section is secured, the hydraulic unit continues to climb up, section by section, as the crane slowly builds itself higher.


Mirrors
Curved mirrors focus the Sun's power on the central processing tower.
Office
Amazingly, behind the parabolic reflector mirror, people are working.
Furnace
The Sun's rays are focused here onto a dark-coated, 3,800°C furnace.

© Science Photo Library

Renewable energy

With the Earth's supply of fossil fuels perpetually declining, new and exciting energy systems are being designed to exploit sustainable resources

Each year the global population is increasing at an exponential rate, creating a ravenous demand for energy. Fossil fuels cannot sustain this and it is forcing governments across the globe to re-evaluate how they are going to provide power for future generations.

Luckily, right now numerous systems are being designed and developed worldwide to address this issue, demonstrating novel and creative methods of exploiting the renewable resources with which Earth is privileged. Harnessing the power of sunlight, wind, rain, tides and geothermal heat, these technologies are slowly repositioning the balance of power away from finite resources and towards sustainable ones, mitigating long-held fears over a world post-oil and delivering power generation on a domestic as well as industrial level. Take a closer look at some of the most promising technologies.

An operational Pelamis Wave Energy Converter is buffeted by ocean waves

© Pelamis

5 TOP FACTS RENEWABLE ENERGY

Megawatt
1 The world's largest wind turbine is the Enercon E-126, which has a rotor diameter of 126m. The E-126 turbine is rated at a particularly whopping six megawatts.

Investment
2 Worldwide investment in renewable energy has risen exponentially year-on-year, increasing from $104 billion in 2007 to a staggering $150 billion in 2009.

African
3 Kenya is the current world leader in the number of domestic solar power systems installed per capita, with over 300,000 12-30 watt systems sold each year.

Greenest
4 The current world leader in renewable energy production is China, which in 2009 produced 682 TWh of electricity through water, wind, biomass and solar.

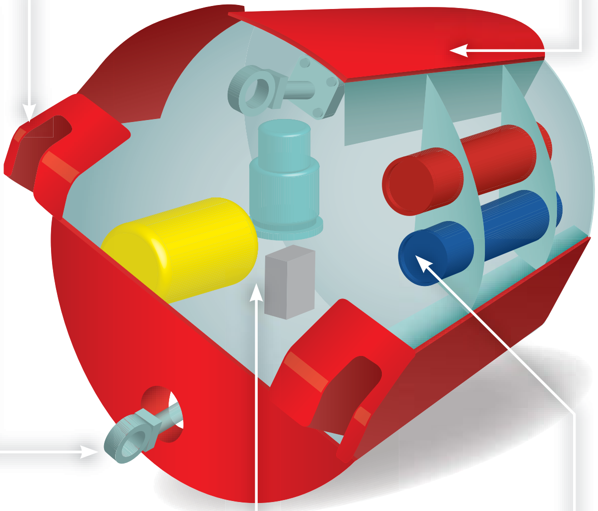
Future
5 Recent estimates by scientists forecast the world will run out of the majority of fossil fuels by 2070, with natural gas being the first to go, followed quickly by oil and coal.

DID YOU KNOW? *The largest solar power station in the world is situated in California's Mojave Desert*

Solar furnace

Generating power from sunlight

The Odeillo-Font-Romeu solar power station in the Eastern Pyrenees, France. Positioned in front of the reflector (out of view here) is an array of 63 flat orientating mirrors that automatically track the motion of the Sun, reflecting incident radiation onto the parabolic reflector mirror. The reflector comprises 9,500 mirrors that concentrate the Sun's rays onto a dark-coated furnace at its focus (central tower). The system is capable of producing thermal power of 1,000 kilowatts, and achieving a temperature of 3,800 degrees Celsius within the furnace.



Hydraulic ram
The hydraulic rams resist the motion of the waves, which in turn pump high-pressure hydraulic fluid into the unit's hydraulic motors.

Heave hinged joint
The position for the section's horizontal axis joint.

Sway hinged joint
The vertical axis is connected here to the Converter's other sections.

Motor/generator set
The hydraulic motor converts the hydraulic fluid pumped into it by the rams into torque and rotation in order to drive the unit's generators.

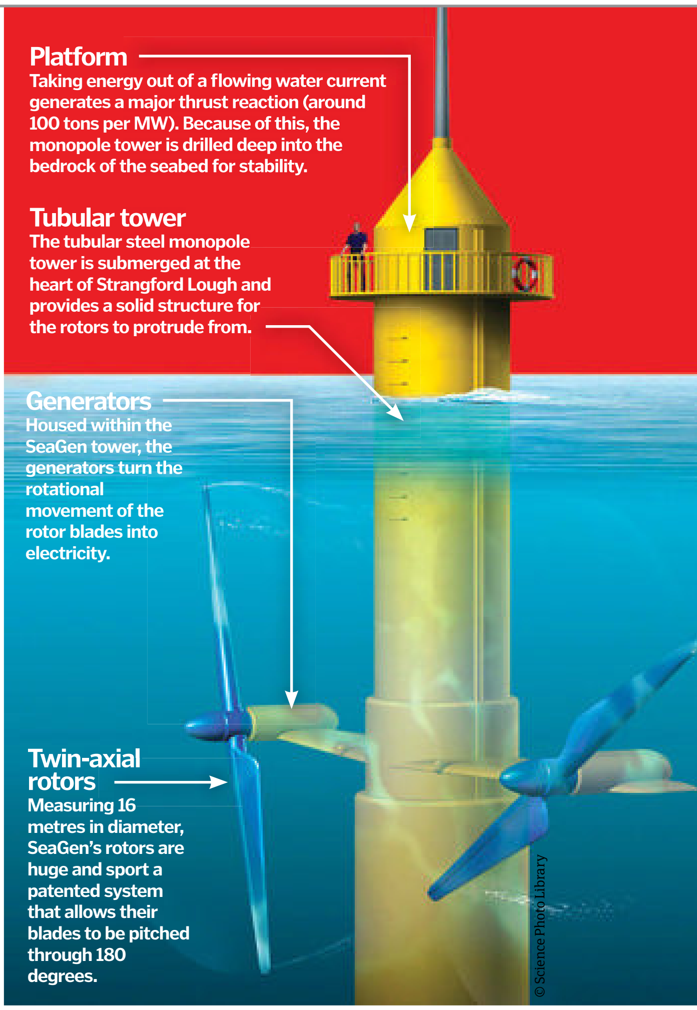
High-pressure accumulators
This allows the Pelamis's pump mechanism to be a manageable size and also to operate quicker, allowing it to moderate demand and smooth out the wave's pulsations.

Pelamis Wave Energy Converter

The Pelamis Wave Energy Converter from Pelamis Wave Power is a system designed to generate renewable electricity from ocean waves. The system consists of a semi-submerged, articulated structure (180 metres long and four metres in diameter) comprising cylindrical sections linked by joints. These joints, under the pressure of wave-induced motion, move and are resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors to drive electrical generators and produce electricity. This energy is then fed from each joint down an umbilical and then carried back to shore in a single large seabed feed. Each Pelamis Converter is rated at 750kW and on average a unit will produce 25-40 per cent of that rating annually, which is the annual electricity demand for roughly 500 homes.

A second-generation Pelamis Wave Energy Converter at the European Marine Energy Centre, Orkney

© Pelamis



Platform
Taking energy out of a flowing water current generates a major thrust reaction (around 100 tons per MW). Because of this, the monopole tower is drilled deep into the bedrock of the seabed for stability.

Tubular tower
The tubular steel monopole tower is submerged at the heart of Strangford Lough and provides a solid structure for the rotors to protrude from.

Generators
Housed within the SeaGen tower, the generators turn the rotational movement of the rotor blades into electricity.

Twin-axial rotors
Measuring 16 metres in diameter, SeaGen's rotors are huge and sport a patented system that allows their blades to be pitched through 180 degrees.

© Science Photo Library

SeaGen tidal generator

The SeaGen tidal generator from Marine Current Systems is an operational tidal system based in Strangford Narrows in Northern Ireland. The system consists of twin submerged axial-flow rotors – measuring 16 metres in diameter – which are attached to a central machine and control tower that is fixed to the seabed. Both rotors on the SeaGen sport a unique feature that allows the blades to be pitched through 180 degrees, allowing them to operate in both tidal directions. Appearing like an upside-down submerged windmill, SeaGen works by converting high-velocity currents into usable electricity throughout the tidal cycle – much as a windmill utilises the power of the wind to rotate its sails. Indeed, its large-scale rotors – aided by the 400 million gallons of water that flow past it twice a day – can develop a rated power of 1.2 MW at a current velocity of 2.4m every second. This gives SeaGen the ability to deliver about 10 MW per tide, which annually amounts to 6,000 MWh of energy.

SeaGen is capable of raising its rotors out of the water for ease of maintenance

© Fundy

> "The Roscoe Wind Farm in Texas has an epic 627 turbines"

Wind turbines

Taking the power-generating capabilities of windmills to the next level

Among the world's most developed renewable energy systems, wind turbines take the mechanics of a traditional windmill and upscale them dramatically in order to obtain energy from wind which can be converted into electricity. The most common wind turbine in production is the horizontal axis variety. These consist of a main rotor shaft and electrical generator at the top of a large, tapered, cylindrical tower. This type of turbine allows the wind to rotate its three fixed blades in order to generate mechanical, rotational energy, which is then in turn converted into electrical energy by the installed electrical generator. The slow-to-fast rotation of the rotor and blades is aided by an installed gearbox, which allows for a smooth transition in speeds depending of wind strength. Wind turbines are often installed en masse in highly windy areas, such as coastal regions, in massive wind farms. The largest windfarm in the world is the Roscoe Wind Farm in Texas, which has an epic 627 turbines and total installed capacity of 781.5 MW.

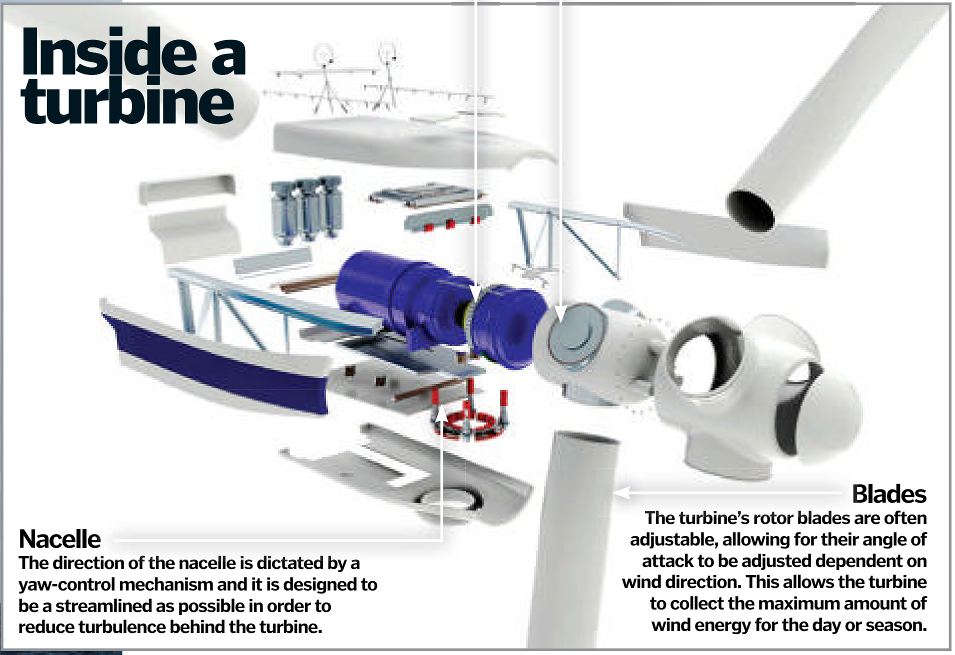
An Enercon E-126, the largest wind turbine in the world, situated in Germany

A wind farm 28km off the shore of Belgium's part of the North Sea

Operation
The turbine's generator, gearbox and yaw-control mechanism are housed here.

Tower
The turbine's tall tower is a crucial element of its design. In areas with high wind shear, the overall wind speed can increase by 20 per cent and the power output by 34 per cent for every 100 metres of elevation.

Inside a turbine



Generator
The turbine's generator converts the rotor's rotational energy into electrical energy to be sent to the grid or storage device.

Gearbox
Helps initiate the rotor's movement and then aids its velocity dependent on wind speed to maximise energy conversion.

Nacelle
The direction of the nacelle is dictated by a yaw-control mechanism and it is designed to be a streamlined as possible in order to reduce turbulence behind the turbine.

Blades
The turbine's rotor blades are often adjustable, allowing for their angle of attack to be adjusted dependent on wind direction. This allows the turbine to collect the maximum amount of wind energy for the day or season.

© DK Images

Head to Head

DOMESTIC RENEWABLE ENERGY SYSTEMS

MOST EXPENSIVE

© Sju

1. Solar

Solar panels offer an established form of energy generation on a domestic level. However, they can be expensive and are only useful when the weather is fine.

MOST INTRUSIVE

© Eirbyte

2. Wind

Small wind turbines can be bought and attached to the tops of buildings to supply a small amount of electricity each year. They are cheap but currently inefficient.

MOST CONSISTENT

© Heidas

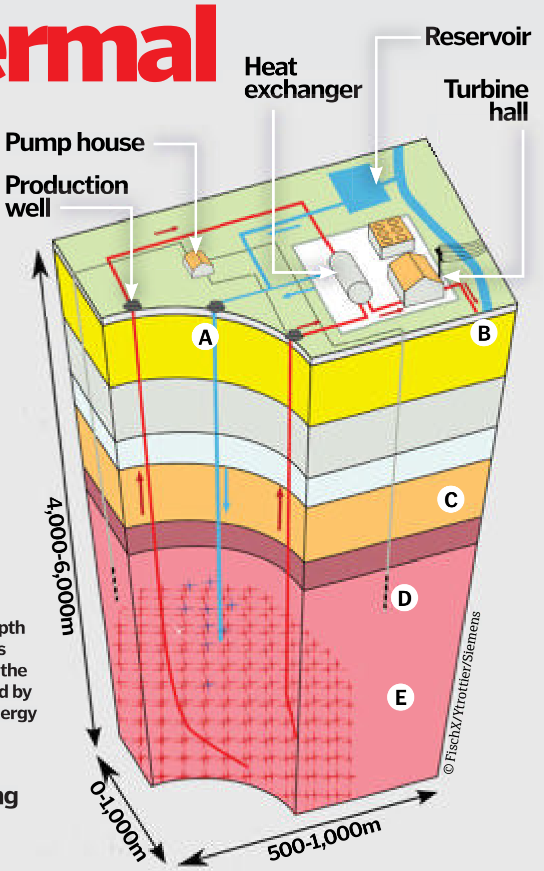
3. Water

If you are lucky enough to live by a stream or river, small water turbine generators allow you to exploit its gentle amble for a small and ensured power return.

DID YOU KNOW? *Two solar updraft towers have been approved for construction so far, one in Namibia and the other in Spain*

Geothermal power plants

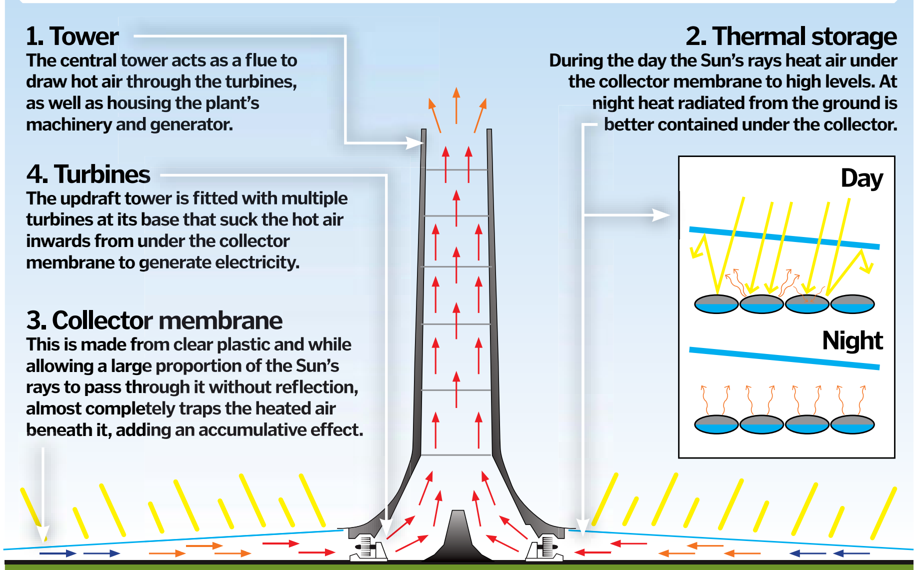
Geothermal energy is power extracted from heat stored inside the Earth. The heat is generated from radioactive decay, volcanic activity, core convection and solar energy absorbed at the Earth's surface. Geothermal power plants pump water down a borehole into hotspots a few kilometres beneath the Earth, then force it out of a second borehole into a steam turbine to produce electricity.



© FischX/Ytrottier/Siemens

A diagram of a geothermal power plant showing the drilling of a borehole to a depth of 5km. At this depth, a layer of water has formed from rainwater draining through the ground (blue arrows). The water is heated by magma, and the borehole enables the energy of the heated water to be extracted.

A. Injection well
B. Hot water to district heating
C. Porous sediments
D. Observation well
E. Crystalline bedrock



1. Tower
The central tower acts as a flue to draw hot air through the turbines, as well as housing the plant's machinery and generator.

2. Thermal storage
During the day the Sun's rays heat air under the collector membrane to high levels. At night heat radiated from the ground is better contained under the collector.

4. Turbines
The updraft tower is fitted with multiple turbines at its base that suck the hot air inwards from under the collector membrane to generate electricity.

3. Collector membrane
This is made from clear plastic and while allowing a large proportion of the Sun's rays to pass through it without reflection, almost completely traps the heated air beneath it, adding an accumulative effect.

Solar updraft towers

An elegant proposed system to exploit solar energy, the solar updraft tower works by combining the chimney effect – where cold air is drawn upwards by reduced local pressure – the greenhouse effect and a wind turbine. The power plant works by trapping air heated by the Sun under a large greenhouse-like circular membrane that, through convection and the chimney effect, causes the hot air to be sucked in towards and up the central tower. As the hot air travels up the tower the airflow drives a selection of turbines that in turn produce electricity. Definitely one to watch in the future…

Interview

How It Works spoke to Kamil Shar from Sanyo Solar about the exciting new sustainable systems becoming available for home use

How It Works: Energy efficiency is crucial for solar cells, how efficient are Sanyo Solar's modules?

Kamil Shar: The energy conversion efficiency for modules is essentially the barometer for quality and this is really the core feature of our product, offering a lot of value for the end users on a domestic level. It is the residential market that we are focusing on primarily and the reason for this is that due to the module's high efficiency we are able to offer more value in a limited space installation area. So your average terraced house can only get up to a 2kW system size, and if they are trying to achieve that with lower-quality modules they wouldn't have enough space to make that installation. With our new HIT modules we can achieve a record energy conversion efficiency of 23 per cent at the R&D level; on a domestic level 21.1 per cent.

HIW: How has the conversion efficiency for solar panels been progressing, has it been developing incrementally?

KS: It has been incremental. Previous to that it was around 20 per cent and before that the number rose fast only in the last five to ten years. That is mainly due to the amount of investment we are putting into our R&D, as the market has grown massively over the past couple of years in Europe.

HIW: What level of power is one of your modules going to provide the average domestic consumer and how is created energy used?

KS: The way that the system works in the UK [as of 1 April 2010] is we have a subsidiary system called the feed-in tariff and how that works is that if you have a solar installation on your roof it will be connected to the national energy grid. So any electricity you are generating and not using will be fed back into the grid. The dynamics of the feed-in system benefit self generation as the government has set a tariff of 40 pence for every kW hour of electricity generated and that amount is paid to the system owner whether they use the electricity or not.

HIW: So the user isn't generating electricity that can only be used in their own home, it can be fed into the grid and used anywhere?

KS: That is correct. However, if there is an electricity demand in the house when the electricity is being generated then it will be used to power that household. But if there is no one in at the time or no energy is required it will be fed into the grid. So what we are suggesting to people who invest in our systems is that they should alter their energy habits to generate electricity and use it during the daytime, as it is free and also grants you the tariff all at the same time.

HIW: In Britain it is not particularly sunny, would that jeopardise the 21.1 per cent conversion efficiency?

KS: The figures are generally measured based on industry criteria so all module manufacturers would have to conform to certain criteria when they are measuring cell conversion efficiency, that way everyone is on an even playing field and we're not promoting statistics from Spain in the UK. So yes, dependent on conditions there will be fluctuations but they are impossible to quantify, as we wouldn't know how much light there was one day to the next.

HIW: How efficient can silicon solar cells actually become? It is currently 21.1 per cent but is there a theoretical cap or barrier that cannot be overcome?

KS: Currently, 29 per cent is the theoretical maximum for these crystalline-based technology.

HIW: When do you think that figure is going to be hit?

KS: It's very hard to predict as the closer you get to 29 per cent the harder it is to achieve it. It will be achieved, but it will be dependent on technological advancement and R&D investment. However, with even a current solar set-up now, such as our module and system, users would see a positive return on the initial outlay after eight to ten years and then for the next ten to 12 years, because the feed-in tariff is fixed for 20, they'd be generating income of roughly ten per cent the initial outlay, all the while benefiting from free electricity.

One of Sanyo Solar's 21.1 per cent efficient HIT modules

> "The main tools are dynamite and dragline excavators"

Coal mining

Coal miners literally move mountains to feed our insatiable appetite for cheap energy

There's something brutally simple about coal mining. Take away the monstrous new machinery and eco-friendly marketing jargon and it's the same dirty, dangerous job it's always been: find the black stuff and dig it up.

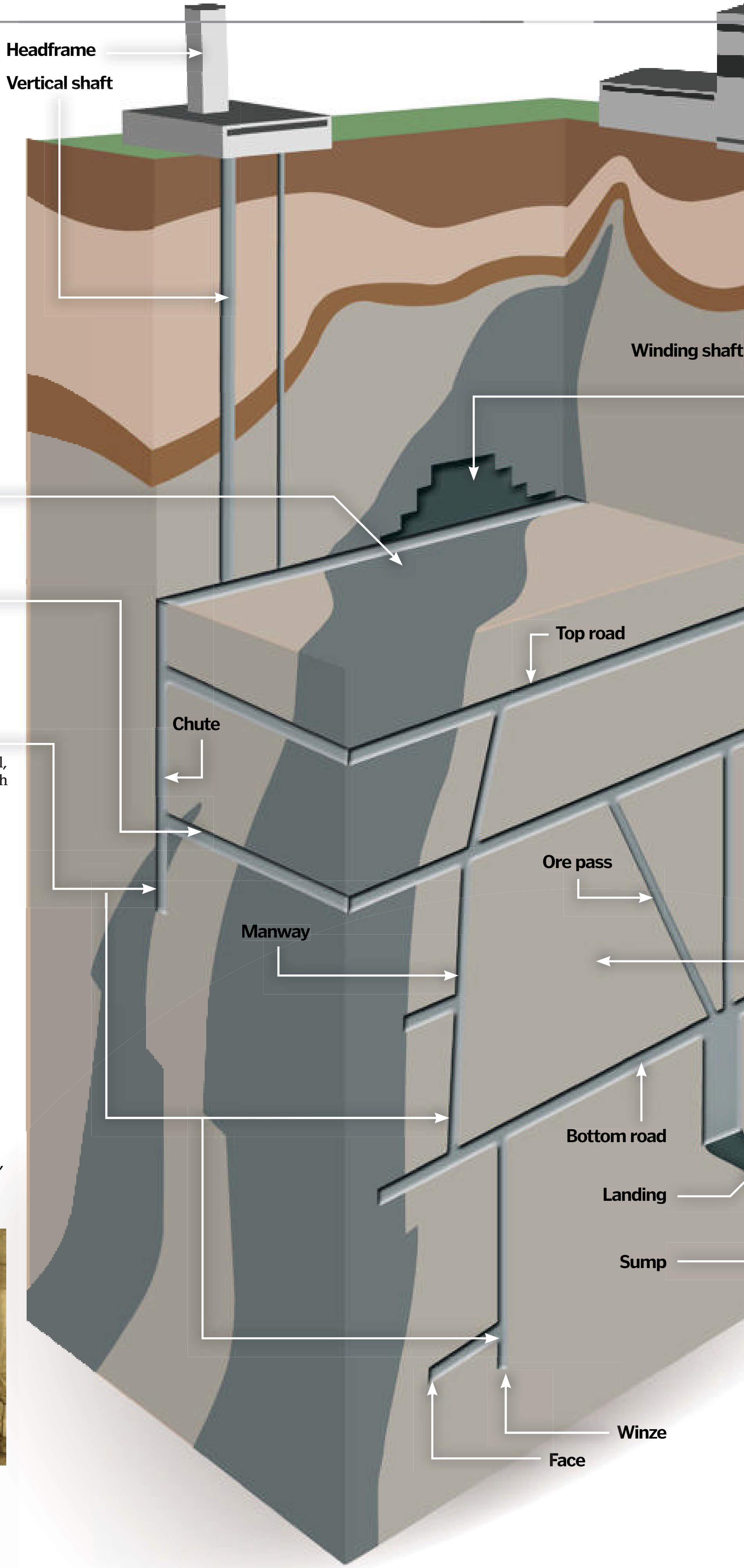
The two major schools of coal mining are surface mining and underground mining. To qualify for surface mining, the coal seam must lie within 60 metres of the surface. The miners' job is to remove all of the 'overburden' – the cubic tons of rock, soil and trees above the coal seam – and expose the coal layer for extraction. The main tools of the trade are dynamite and dragline excavators, 2,000-ton behemoths that can move 450 tons of material with one swoop of their massive buckets.

Perhaps the most dramatic and controversial surface mining technique is Mountaintop Removal (MTR), in which miners use explosives and heavy machinery to literally knock the top off a mountain – up to 200 metres below the peak – to get at the rich coal beds beneath.

Underground mining is decidedly more difficult and dangerous. In smaller mines, workers still use conventional methods, blasting and digging out large 'rooms' supported by thick 'pillars' of untouched coal. But that won't cut it for modern mining operations that regularly remove over 100 megatons (1 million tons) of raw coal each year.

The go-to machine of the high-volume coal mine is a continuous miner. This long, low-slung machine rips through coal faces with a wide rotating drum armed with hundreds of drill bits. Each bit is sprayed with a fine mist of water, cooling the cutting surface and neutralising coal dust emissions. Using built-in conveyors, the machine rolls the coal off its back, where it's transported to the surface by haulers or conveyor belts.

Another day at the office for Short Round...



Coal seam
Mining companies go to great expense to reach these long horizontal fields of coal that range in thickness from a mere 50 centimetres to over four metres in height.

Cross cuts
Horizontal passageways are tunnelled through the ore bed to provide critical ventilation and to allow motorised access to coal seams via flat rail cars, commonly known as 'mantrips'.

Winzes, manways, chutes and drifts
A well-worked mine is a labyrinth of vertical, horizontal and sloped shafts carved through the coal by continuous mining machinery.

5 TOP FACTS COAL MINING

Worldwide production
1 Back in 2008, the world's coal mines produced 5,845 megatons of black coal and 951 megatons of brown coal. Makes you wonder how long it's going to last, doesn't it?

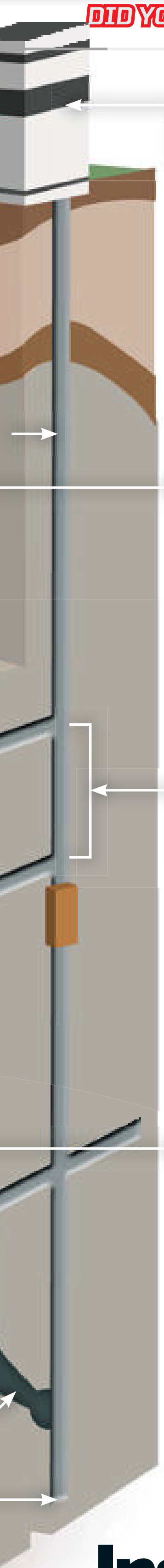
The coal king
2 China is by far the largest coal producer in the world with a staggering 18,557 mines. To compare, the United States has 1,458 mines and the UK has just 46.

Old friend steel
3 The steel industry is one of the heaviest consumers of coal. Worldwide steel plants burned 1,327Mt of coal – in its purified form called coke – in 2008.

Let there be light
4 Over 40 per cent of the world's electricity is provided by coal. China burns coal for 81 per cent of its electricity, while the US uses coal for 49 per cent of its electricity.

Super scrapers
5 A continuous mining machine can extract eight tons of coal per minute. Some quick maths will tell you that's 480 tons an hour, 11,520 tons a day and 4.2 million tons a year.

DID YOU KNOW? Coal provides over 23 per cent of the world's energy needs



Winding tower
Also called a headframe, the winding tower uses powerful drum hoists and thick steel cables to pull men, machines and coal from the deepest reaches of the main shaft.

Room and pillar
In conventional coal extraction, miners use explosives to carve out large caverns in the coal seam, leaving a thick pillar of undisturbed coal for roof support.

Levels and decks
Extraction starts with the coal seam closest to the surface, then miners descend through a thick section of rock – or 'deck' – to reach the next workable level.

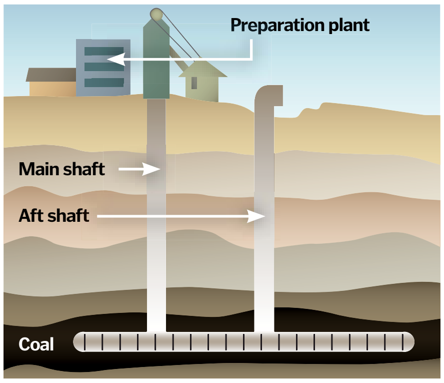
Panel
In longwall mining, miners carve four tunnels around a rectangular chunk of rock – called the 'panel' – hundreds of metres wide and thousands of metres long. The panel is then harvested from floor to ceiling with automated machinery called shearers.

Inside a coal mine

Take a trip into the claustrophobic depths of the mine

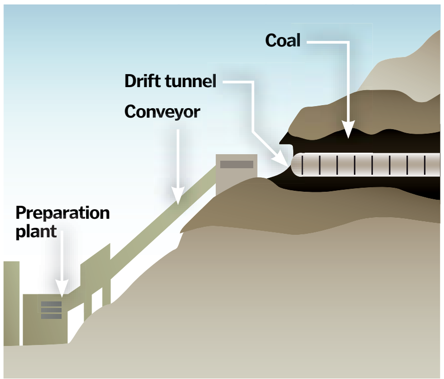
Types of coal mine

A closer look at the numerous different methods and mines that are often used to extract coal



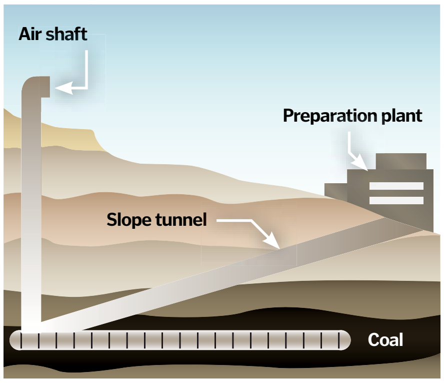
Shaft mine

Miners and equipment are transported down vertical shafts hundreds or thousands of metres deep to access fertile coal seams.



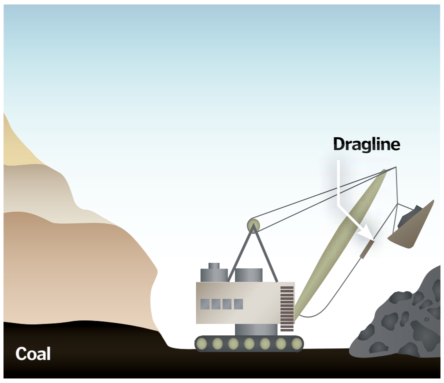
Drift mine

The simplest method of underground mining, the coal seam is accessed by digging horizontally into the side of a hill.



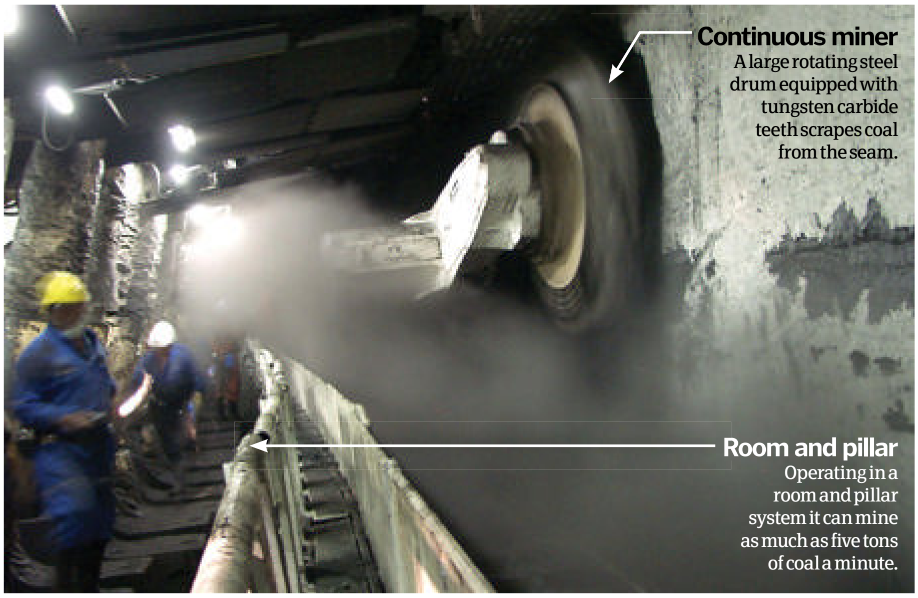
Slope mine

For a shallow underground coal seam, miners dig a slanted or 'sloped' shaft and remove the coal via long conveyor belts.



Surface mine

In a surface mine (or strip mine), miners remove a horizontal layer of soil and rock called the overburden to expose a coal seam.



Continuous miner
A large rotating steel drum equipped with tungsten carbide teeth scrapes coal from the seam.

Room and pillar
Operating in a room and pillar system it can mine as much as five tons of coal a minute.

Image © Gebr. Eickhoff Maschinenfabrik und Eisengießerei

Head to Head

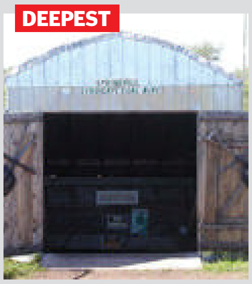
THE BIGGEST, DEEPEST AND MOST PRODUCTIVE COAL MINES ON EARTH

BIGGEST

1. El Cerrejón

The largest surface mine in the world, this 69,000 hectare pit in Northern Columbia produces over 31Mt of bituminous coal per year, transporting it to the coast for export on its own 150km railroad.

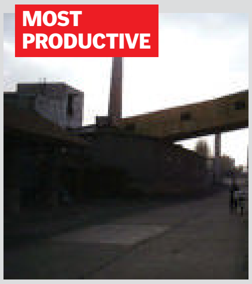
DEEPEST



2. Cumberland Mine

Closed in 1958 after an earthquake-triggered collapse killed 74 miners, this Nova Scotia mine had sloped shafts over 4,200 metres deep, the deepest coal operation on record.

MOST PRODUCTIVE



3. Shandong Mine

The most productive mine in the world, this Chinese operation dug up 117.8Mt of raw coal in 2008. That's over ten per cent of the total annual coal production of the United States.

Learn more

For more information about coal mines head on over to **www.bbc.co.uk/nationonfilm/topics/coal-mining/** where you can take a trip through the coal mines of north-east England from the Thirties to the Nineties.

> "The polycarbonate layer behind it forces the glass to shatter internally rather than outwards"

© Science Photo Library

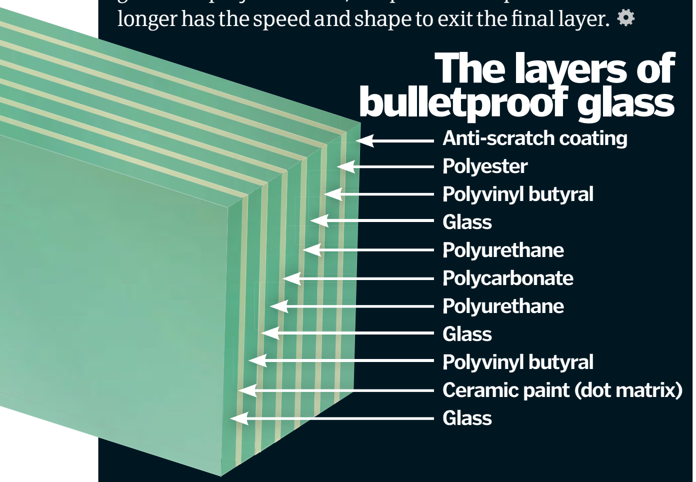
Bulletproof glass explained

Shattering the science behind what makes the breakable unbreakable

Bullet-resistant glass works by absorbing a bullet's kinetic (movement) energy and dissipating it across a larger area. Multiple layers of toughened glass are reinforced with alternated layers of polycarbonate – a tough but flexible transparent plastic which retains the see-through properties of glass. As a bullet strikes the first glass layer, the polycarbonate layer behind it forces the glass to shatter internally rather than outwards.

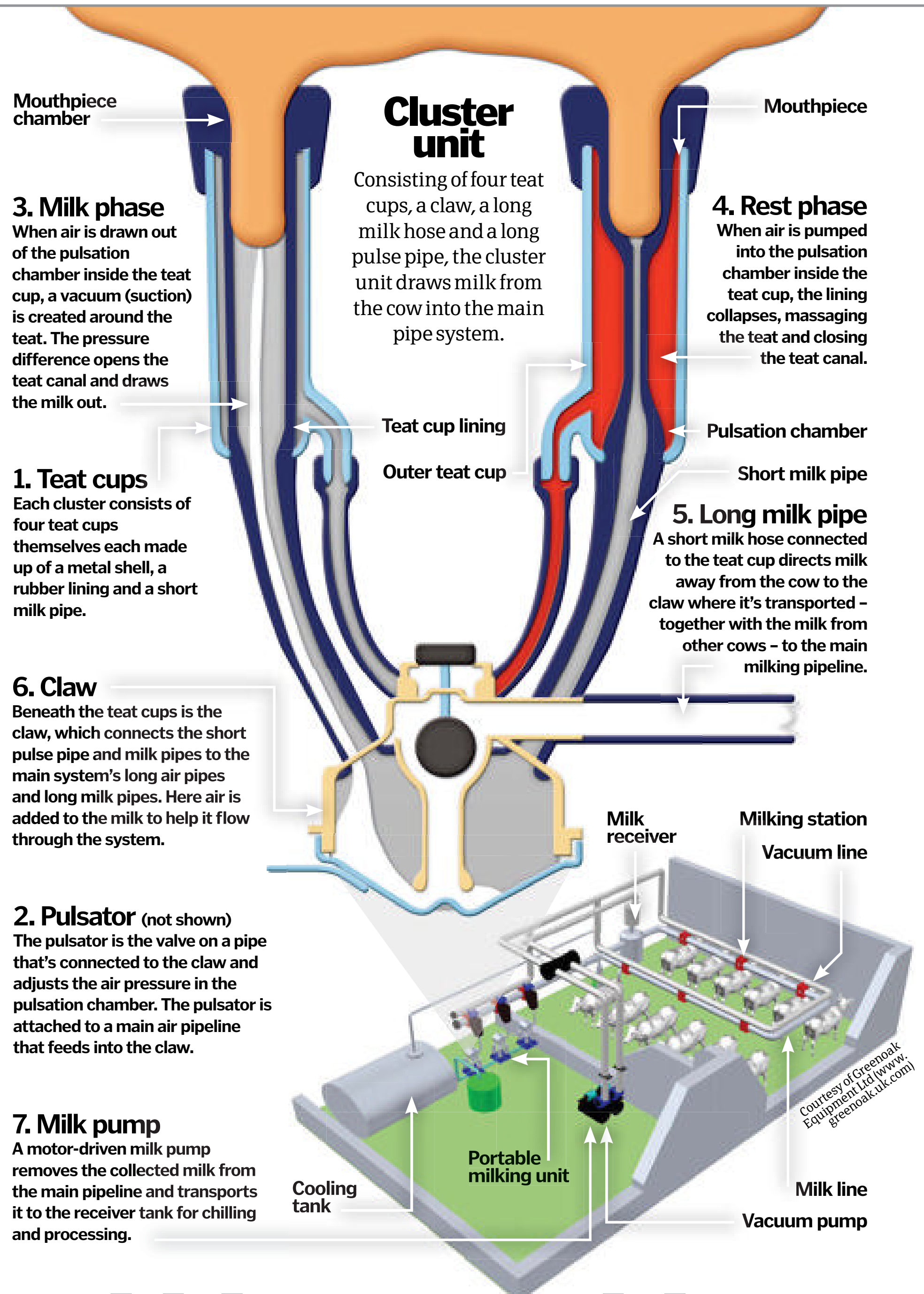
This process absorbs some of the bullet's kinetic energy. The high velocity impact also flattens the bullet's head. Imagine trying to pierce through a sheet of cotton with the top end of a pencil. It would be very difficult compared to using the sharp pointed end. The same principle applies here. The flat-headed bullet struggles to penetrate the layer of polycarbonate. As the bullet travels through each layer of glass and polycarbonate, the process is repeated until it no longer has the speed and shape to exit the final layer.

The layers of bulletproof glass



DID YOU KNOW?

One-way bullet-resistant glass is often used in military situations. While protecting against incoming bullets, shots can still be returned unaffected.



Cluster unit
Consisting of four teat cups, a claw, a long milk hose and a long pulse pipe, the cluster unit draws milk from the cow into the main pipe system.

3. Milk phase
When air is drawn out of the pulsation chamber inside the teat cup, a vacuum (suction) is created around the teat. The pressure difference opens the teat canal and draws the milk out.

4. Rest phase
When air is pumped into the pulsation chamber inside the teat cup, the lining collapses, massaging the teat and closing the teat canal.

1. Teat cups
Each cluster consists of four teat cups themselves each made up of a metal shell, a rubber lining and a short milk pipe.

5. Long milk pipe
A short milk hose connected to the teat cup directs milk away from the cow to the claw where it's transported – together with the milk from other cows – to the main milking pipeline.

6. Claw
Beneath the teat cups is the claw, which connects the short pulse pipe and milk pipes to the main system's long air pipes and long milk pipes. Here air is added to the milk to help it flow through the system.

2. Pulsator (not shown)
The pulsator is the valve on a pipe that's connected to the claw and adjusts the air pressure in the pulsation chamber. The pulsator is attached to a main air pipeline that feeds into the claw.

7. Milk pump
A motor-driven milk pump removes the collected milk from the main pipeline and transports it to the receiver tank for chilling and processing.

Courtesy of Greenoak Equipment Ltd (www.greenoak.uk.com)

Milking machines

Discover how to get milk from a cow

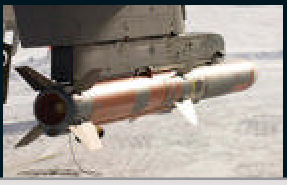
The milk is extracted using a vacuum applied to the cow's teats. Milk stored in the udder is drawn into a system of pipes leading to a receiver tank where the milk is collected before being passed to the cooling tank.

A 'cluster' of four teat cups – each consisting of a stainless steel shell, a flexible rubber lining and a short pulse pipe – are attached to the teats. Between the outer shell and lining is a pulsation chamber that collapses with the addition of air from a pulsator. When the chamber is devoid of air (milk phase) a vacuum is created, which gently draws milk from the teat. When the chamber is filled with air (rest phase) the lining of the teat cup collapses and massages the teat. Continued repetition of these phases not only aids milk production by mimicking the action of a suckling calf, it also promotes blood circulation.

To help the milk flow away through the pipeline, once out of the cow the milk is mixed with air added by a claw, the claw connects the teat cups to the milk and pulse tubes.

THE STATS AIM-9

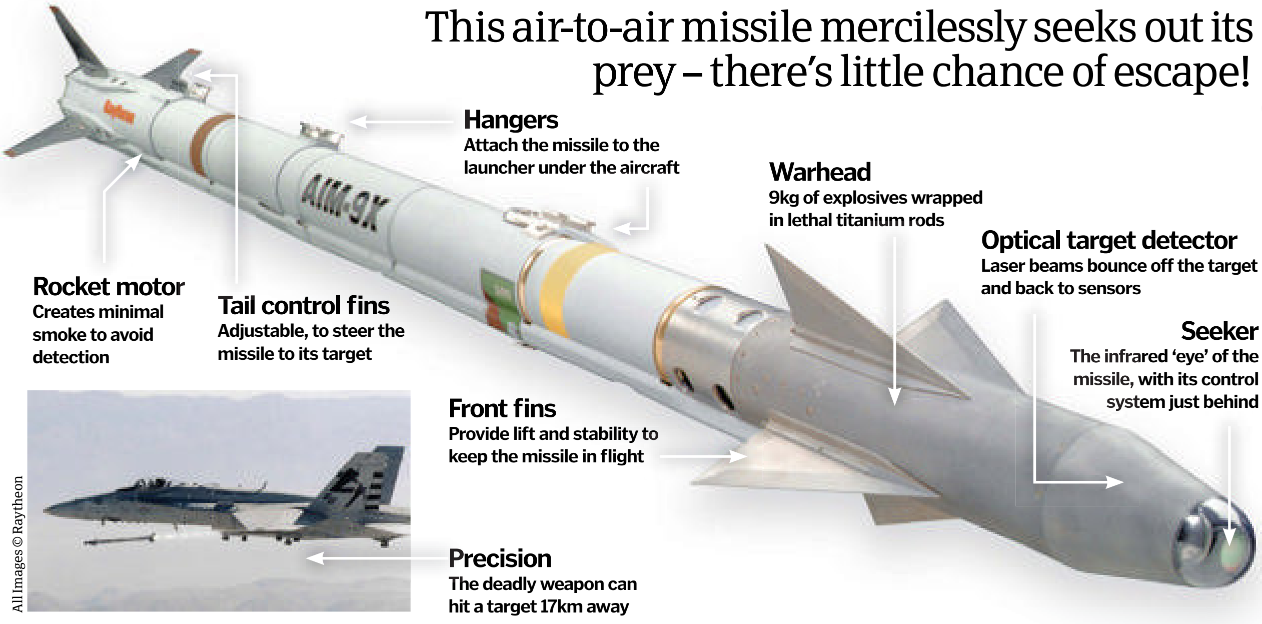
TOP SPEED **Mach 2.5** LENGTH **3.0m** WARHEAD **9.5kg**
WEIGHT **85kg** RANGE **17.7km** COST **$85,000**



DID YOU KNOW? *The missile flies towards its target at speeds of 3,060km/h (1,900mph)*

Missiles in action: AIM-9 Sidewinder

This air-to-air missile mercilessly seeks out its prey – there's little chance of escape!



Hangers
Attach the missile to the launcher under the aircraft

Warhead
9kg of explosives wrapped in lethal titanium rods

Optical target detector
Laser beams bounce off the target and back to sensors

Seeker
The infrared 'eye' of the missile, with its control system just behind

Rocket motor
Creates minimal smoke to avoid detection

Tail control fins
Adjustable, to steer the missile to its target

Front fins
Provide lift and stability to keep the missile in flight

Precision
The deadly weapon can hit a target 17km away

All Images © Raytheon

Named after a venomous snake that is sensitive to infrared and so can sense the heat of its prey, the deadly Sidewinder missile does much the same.

First tested in 1953, the Sidewinder is a heat-seeking, short-range air-to-air missile used by fighter aircraft. Once launched, it will fly towards a hot target – usually the engines of an aircraft or another missile.

The key to the system is hidden in the nose of the missile. The seeker consists of an array of sensors that react to infrared light; similar in principle to the CCD sensor in a digital camera but simpler in that it only judges its surroundings as 'very hot' or 'not very hot'. In other words it can 'see' heat. The sensors, plus its assembly of mirrors and lenses, spin off-centre so that they can scan a wide vista and also work out where the heat is in relation to the missile. For instance, if the target is over to the right, the sensors will detect more infrared when they are aimed in that direction.

The sensors feed information to the guidance control system that, in turn, move the fins at the back of the missile to steer the Sidewinder towards the target. Or rather, aim it at a point slightly ahead of the target to ensure that it doesn't end up chasing it and never catching it. This is called proportional navigation and effectively anticipates where the target will be at the point of impact.

In fact, the Sidewinder doesn't actually impact with its target, but is designed to explode just before it hits it, to ensure maximum damage. Lasers positioned behind the forward fins emit light, and when the missile is close to the target, the light bounces off it and back to sensors on the missile, telling the systems to trigger the warhead.

The Sidewinder is launched from an aircraft and is initially propelled by a rocket motor that hurls it forward at a speed of Mach 2.5 (about 3,060km/h). Once the fuel has been used, the missile glides the rest of the way to its target.

The warhead

The front mid-section of the Sidewinder is packed with explosives. Like the rest of the missile, though, this 9kg warhead is highly sophisticated. It consists of a high explosive wrapped with around 200 titanium rods, plus an initiator explosive.

When the missile is within range of its target, the low-power initiator is activated. This in turn ignites explosive pellets, which then cause the main charge to explode. This blasts the titanium rods apart into thousands of fragments, which hit the target at high speed, causing cataclysmic damage.

A safety device in the missile means that the warhead cannot be activated unless the missile has been accelerating at 20g for five seconds, therefore ensuring it is at least 2.4km (1.5mi) away from the launching aircraft.

ON THE MAP

Deployment

It is estimated that Sidewinder missiles have killed around 270 people worldwide over the last 50-plus years. Over 110,000 missiles have been produced for 28 countries and just one per cent of them have been used in combat. Here are just some of the war zones where the missile has seen action:

1. Second Taiwan Strait crisis

Date: 1958
Location: Taiwan Strait, Taiwan

2. Vietnam war

Date: 1959-1975
Location: North Vietnam

3. Falklands conflict

Date: 1982
Location: Falkland Islands

4. Lebanese civil war

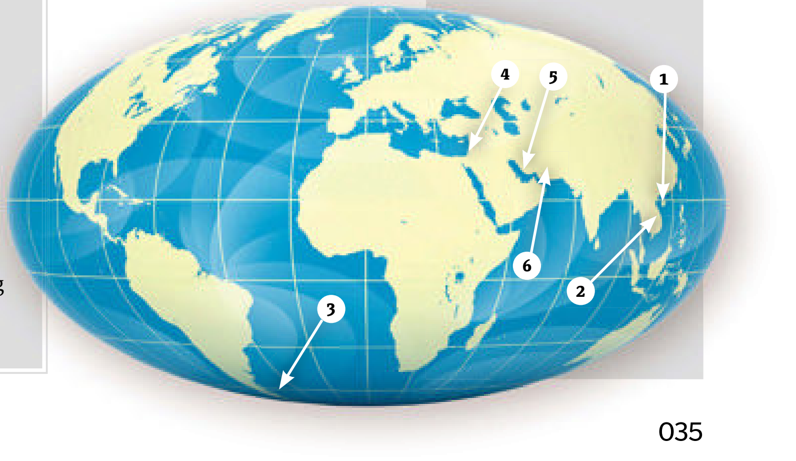
Date: 1975-1990
Location: Bekaa Valley, Lebanon

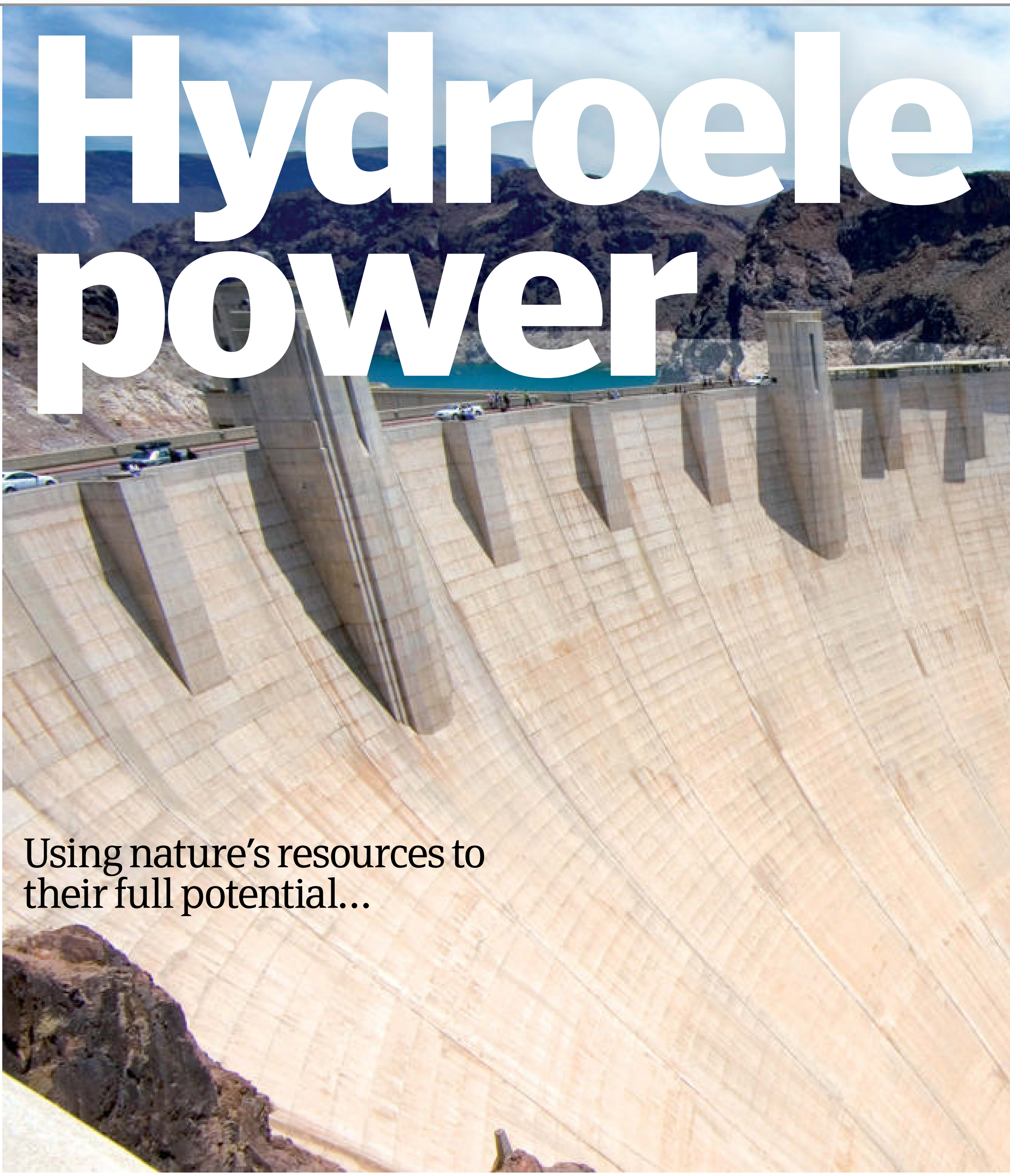
5. Gulf war

Date: 1990-1991
Location: Persian Gulf

6. Soviet-Afghan war

Date: 1979-1989
Location: Afghanistan





Hydroele power

Using nature's resources to their full potential…

Water has been used to power man-made mechanisms for hundreds of years, mostly in food production in the form of a mill wheel to grind corn. However, using the kinetic energy of water probably became a reality earlier than you thought. In 1878, inventor Lord Armstrong lit his home in Northumberland using only the power of a nearby waterfall. It's not until the latter half of the 20th Century that we began to take advantage of the massive potential of hydroelectric power.

Intriguingly, both the dirty and environmentally unfriendly coal power plants and clean, green hydro-power use almost identical technology to generate power. Central to a coal-fired plant is a turbine: coal is burned to produce heat energy, which is used to boil water into steam, which then drives a turbine. Hydroelectric power removes the coal and steam elements and instead, flowing water turns the blades of each turbine.

By damming a river next to a drop in elevation and releasing a controlled flow (and creating a large body of water behind the dam called a reservoir), you can effectively harness the Earth's gravity as an energy source. It's based on the principles discovered by physicist Michael Faraday: when a magnet moves past a conductor, it creates electricity. When the water flowing

Head to Head DAMS

BIGGEST

© Christoph Filnkößl 2006

1. The Three Gorges Dam

Location: Yangtze River, China
Size: It's 2,335 metres long, 101 metres wide and 115 metres at its thickest point. It took 15 years, approximately £25 billion and nearly 14 million tons of cement and materials to construct it.
Fascinating fact: 34 turbines, weighing in at 6,000 tons each, generate 22,500 megawatts for an annual output of 60.7 terawatt hours per year in 2009. It is the world's largest electricity-generating plant of any kind.

TALLEST

© Ibrahim Rustamov

2. Nurek Dam

Location: Vakhsh River, Tajikistan
Size: The Nurek dam is an earth fill dam completed in 1980 when the Soviet Union had control of Tajikistan. At 300 metres it is the world's tallest dam, though the Rogun Dam has a taller proposed height for when it is eventually completed.
Fascinating fact: A comparatively modest nine hydroelectric turbines have a total power output of three gigawatts, but amazingly, since 1994 this has been enough to supply 98 per cent of the nation's total electricity needs.

MOST FAMOUS

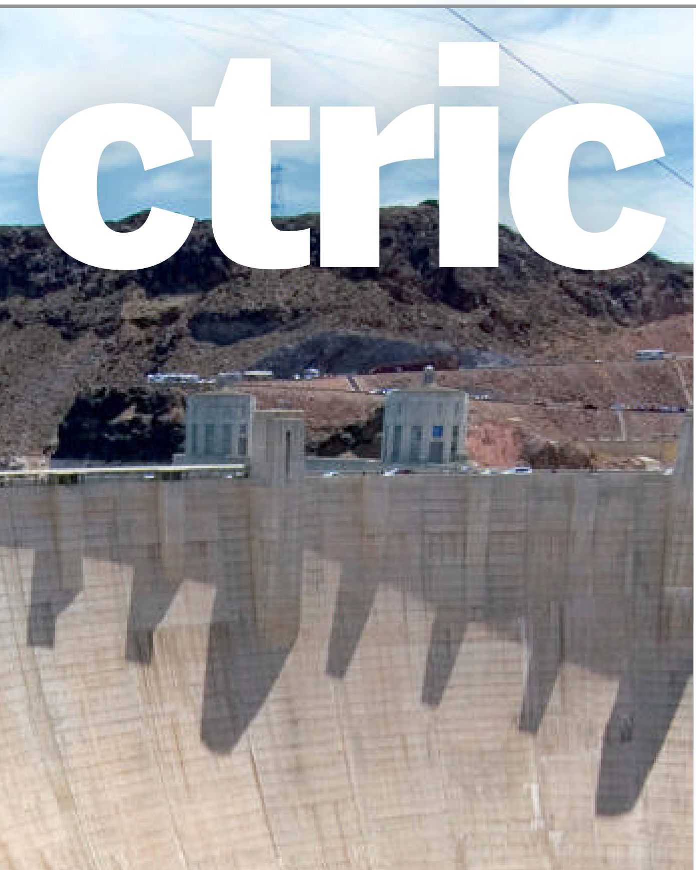
© Adrian Michael 2006

3. Verzasca Dam

Location: Lago di Vogorno, Switzerland
Size: Neither the largest nor the tallest dam at 220 metres high
Fact: As the site for the scene where James Bond dives off into the Verzasca river below in *GoldenEye*, this is one of the world's most famous dams.

DID YOU KNOW? *Between 13,000 to 16,000 people cross the Hoover Dam every day*

ctric



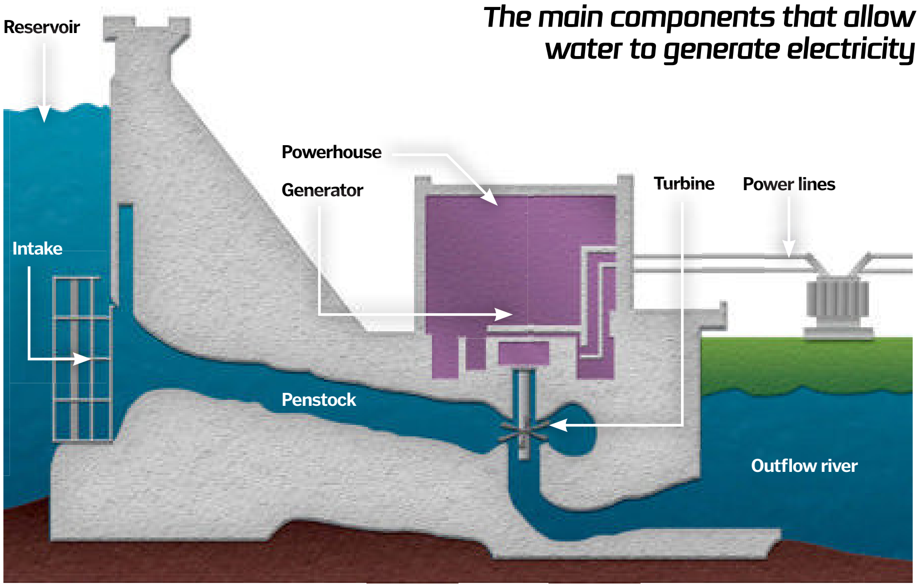
The huge generators inside the Hoover Dam

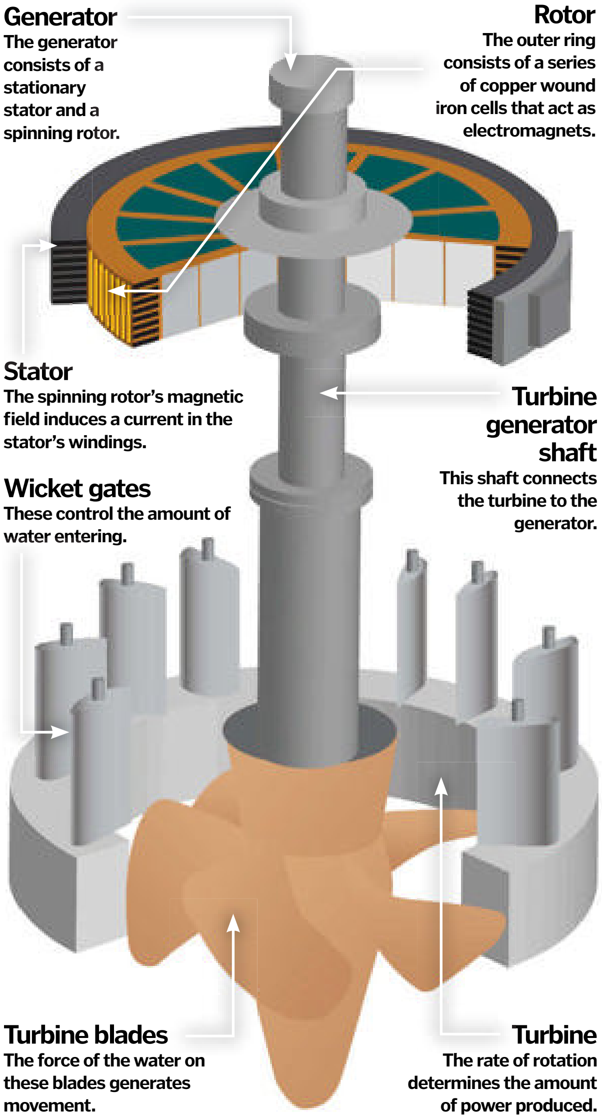
through a hydroelectric turbine turns the blades it rotates a shaft attached to a large disk called a rotor at the opposite end. The rotor is made up of loops of wire with current circulating through them, wound around stacks of magnetic steel. When active, the turbine propeller turns the rotor past the conductors located in the static part of the turbine, known as the stator.

Modern technology in even a single large turbine (which can weigh thousands of tons) can generate an enormous amount of power, but the cost-effectiveness of building the dam as well as the environmental and economic impact of flooding the area behind it can prohibit such ventures.

Inside the dam

The main components that allow water to generate electricity





Generator
The generator consists of a stationary stator and a spinning rotor.

Rotor
The outer ring consists of a series of copper wound iron cells that act as electromagnets.

Stator
The spinning rotor's magnetic field induces a current in the stator's windings.

Turbine generator shaft
This shaft connects the turbine to the generator.

Wicket gates
These control the amount of water entering.

Turbine blades
The force of the water on these blades generates movement.

Turbine
The rate of rotation determines the amount of power produced.

TYPES OF… DAM

1 Saddle
Often constructed as an auxiliary to the main dam, at a dip (or saddle) where water would otherwise escape.

2 Diversionary
Often a controversial construction, these are created with the pure intention of diverting a river from its course.

3 Dry
These are designed to control flooding, allowing the river to flow freely except in times of intense rainfall where flooding is likely.

4 Overflow
These are made with the intention of the river flowing over the top of the dam, usually to measure flow and for drinking water.

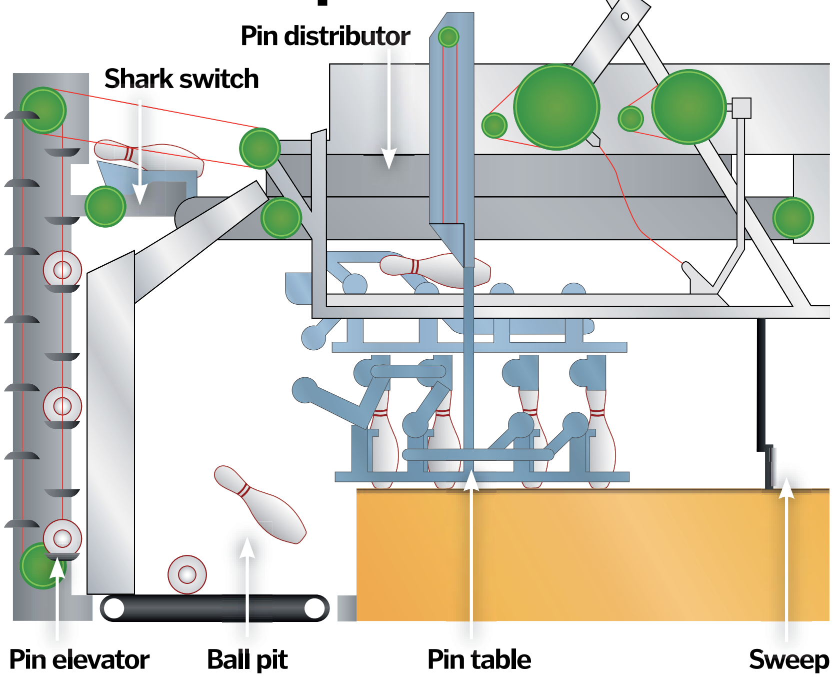
5 Check
Check dams are used to slow he rate of flow of the river with the expressed intention of controlling soil erosion.

Learn more

For more information about the Hoover Dam visit **http://www.pbs.org/wgbh/americanexperience/hoover/** where you can watch a video on how the dam was built and the mammoth task that was involved.

> "The glossy, 60-foot lane is normally constructed out of 39 strips of sugar maple wood"

Side view of a pinsetter



How a bowling alley works

The mechanisms inside a ten-pin bowling alley

Any bowling alley works through a combination of a wooden or synthetic lane flanked by semicylindrical gutter channels, an automated pinsetter machine and ball sorter, and a return ball gully and stacker. The glossy, 60-foot lane is normally constructed out of 39 strips of sugar maple wood, which itself is coated with varying layers of oil down its length. This coating is often heavy towards the bowler end, before dissipating down the alley. This allows a spinning ball more purchase in the final quarter of its journey, enabling pro-bowlers to hit the pins at varying angles. At the pin end of the alley, starting at the termination of the lane, lays the pin-deck. This deck is where the pins are set up and knocked down, and thanks to this constant activity, it is coated with a durable impact-resistant material.

Behind the deck lies the first part of the mechanical pinsetter machine. The pit and shaker collects both the fallen ball and pins before shuffling them to its rear and into mechanical lifts that raise them to above the alley. Once there, the ball is then funnelled onto a metal track which then descends back under the lane to the conveyer belt gully and back to the bowler.

The pins on the other hand get dropped from this elevated position into the pinsetter's turret, where their bottom-heavy weight ensures that they drop base first. Once filled, the turret then waits for the sweep – a mechanical bar that literally 'sweeps' any still-standing pins backwards into the pit – to operate before dispensing a freshly ordered set of pins into the spotting table. This table then lowers the pins gently back onto the pin deck ready for the process to begin again.

In addition, returned balls are automatically slowed and filtered by spinning rubberised pads as they reach the docking station and ball stacker at the bowler end of the lane, as well as scores being automatically logged and recorded by the lane's in-built computer system, and displayed on a screen.

Manufacturing optical fibre

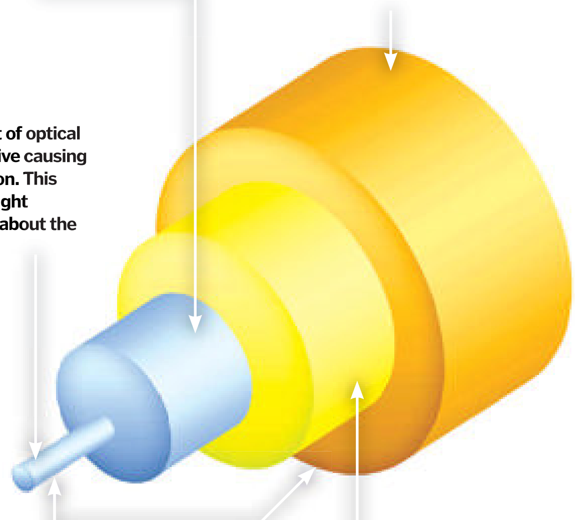
How does a large glass cylinder become a tiny thread of flexible glass?

The tiny filament of glass at the core of a length of optical fibre starts out as two tubes. These tubes are made from fused quartz glass, which is mainly silica to give it flexible properties. First the glass tubes are dipped in corrosive hydrofluoric acid to remove any oily residues, they are then placed in a pair of lathes that spin and heat both tubes with a hydrogen and oxygen flame. When the tubes turn white they are nearing peak temperature and at 2,000°C the tubes melt together to form one longer tube.

This longer tube is placed in another lathe where it is turned and heated by a burner before being injected with chemical gases containing liquid forms of silicon and germanium. The heat and gases cause a chemical reaction that leaves a fine white soot inside the tube. As the burner travels up and down the length of the tube the soot fuses to create a solid glass core. The outer glass tube will form the cladding around the core.

Heating softens the tube and the new glass inside until the tube collapses in on itself. You now have a solid rod called a preform. To thin the preform, it is placed vertically in a drawing tower. This heats one end of the rod to 2,000°C until the glass becomes a honey-like consistency. As the glass melts it stretches under its own weight and becomes a very tall, thin glass fibre.

Pulleys and lasers are used to measure the precise tension and diameter of the fibre, which should be just 125 micrometres thick. The fibre is then passed under an ultraviolet lamp to bake on a protective outer jacket. The finished optical fibre is then rolled onto massive drums.



Optical cladding
Protecting the inner glass core is another layer of glass that has a lower refractive index than the core. The whole glass element is 125 micrometres across.

Plastic jacket
This layer is the last line of defence against damage, such as scratches, to the fragile internal contents. This brings the total diameter of the fibre up to 400 micrometres.

Inner core
The glass component of optical fibre is highly refractive causing total internal reflection. This core measures just eight micrometres across, about the size of a human hair.

Total internal reflection
The high refraction of the glass core and the low refraction of the outer jacket trap light in the core of the fibre so that little-to-no light is absorbed. This is called total internal reflection.

Protective buffer
A resin coating is baked on to protect the delicate glass thread within from moisture damage. With the addition of this layer, the diameter is now 250 micrometres.

5 TOP FACTS LIGHTHOUSES

Fame

1 The builder of the Lighthouse of Alexandria, Sostratus – disobeying orders from the pharaoh Ptolemy – engraved his name and a dedication to the sea gods on the tower base.

Academia

2 The technical term for the study of lighthouses is 'pharology', a word derived from Pharos, the island upon which the great Lighthouse of Alexandria once stood.

War

3 George Meade built many notable lighthouses in the US during the classical lighthouse period. He is remembered in history as the winning general in the Battle of Gettysburg.

Tallest

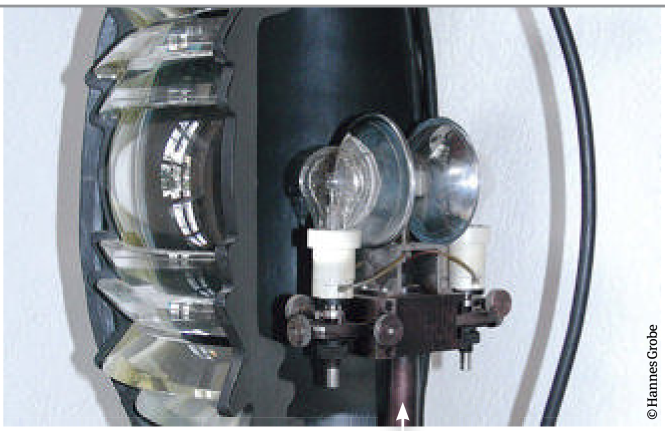
4 The tallest lighthouse in the world is the Yokohama Marine Tower in Yokohama, Japan. The structure flashes alternately green and red every 20 seconds.

Elemental

5 Originally lighthouses were lit merely with open fires, only later progressing through candles, lanterns and electric lights. Lanterns tended to use whale oil as fuel.

DID YOU KNOW? The historic Lighthouse of Alexandria on the Pharos Island, Egypt, could be seen from 30 miles away

A reassuring sight for sailors throughout history



© Hannes Grobe

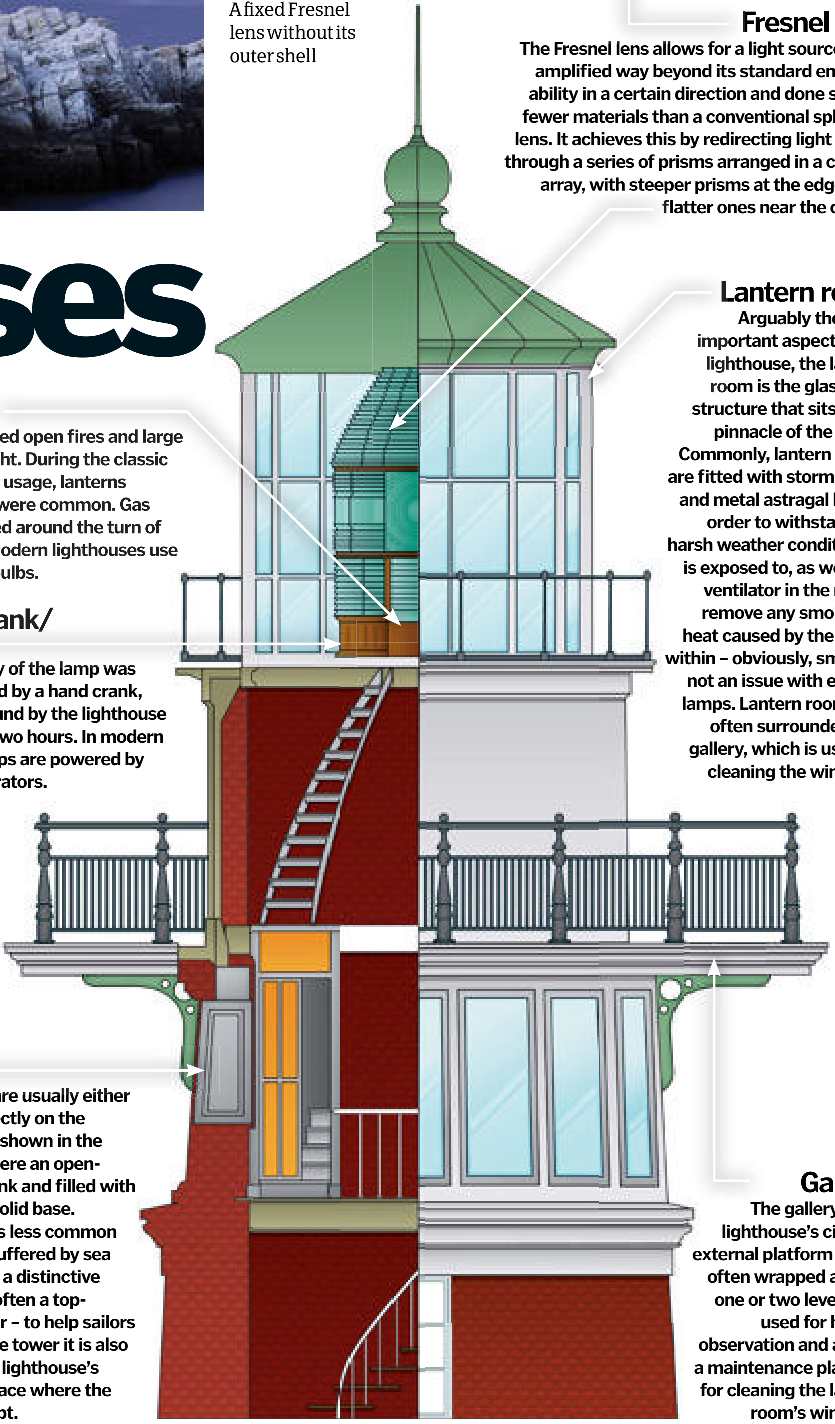
A fixed Fresnel lens without its outer shell

Lighthouses

Including some of the most impressive man-made structures in the world, lighthouses have played a pivotal life-saving role throughout history

Lighthouses work by rhythmically flashing a rotating light in order to transmit a visual signal to surrounding vessels. This is done so that conditions that provide poor visibility can be mitigated by approaching sailors, allowing them to safely manoeuvre while close to the shore. The individual pattern of flashes or eclipses – referred to as the light's character – determine the transmitted message and these can range from collision warnings to weather reports, directional guidance to the position of other vessels and structures. The breadth and types of characters a lighthouse can use is determined by the International Association of Lighthouse Authorities in Paris.

Lighthouse construction emanated from the practice of lighting beacon fires upon hilltops, something first referenced in Homer's *Iliad* and *Odyssey* in the 8th Century BC. However, it was not until 280 BC, when the architect Sostratus built the Great Lighthouse of Alexandria on the island of Pharos, Egypt, that man-made lighthouse structures began to be built across the entire globe. Since then the style and complexity of the structure, light source and fuel has changed greatly, with intricate designs formed dedicated to advancing the light-saving technology. How It Works takes a closer look at a classical lighthouse and its constituent components.



Fresnel lens

The Fresnel lens allows for a light source to be amplified way beyond its standard emitable ability in a certain direction and done so with fewer materials than a conventional spherical lens. It achieves this by redirecting light waves through a series of prisms arranged in a circular array, with steeper prisms at the edges and flatter ones near the centre.

Light source

Early lighthouses used open fires and large candles to create light. During the classic period of lighthouse usage, lanterns burning animal oils were common. Gas lamps were also used around the turn of the 20th Century. Modern lighthouses use electric lamps and bulbs.

Lantern room

Arguably the most important aspect of the lighthouse, the lantern room is the glassed-in structure that sits at the pinnacle of the tower. Commonly, lantern rooms are fitted with storm panes and metal astragal bars in order to withstand the harsh weather conditions it is exposed to, as well as a ventilator in the roof to remove any smoke and heat caused by the lamps within – obviously, smoke is not an issue with electric lamps. Lantern rooms are often surrounded by a gallery, which is used for cleaning the windows.

Rotational crank/machinery

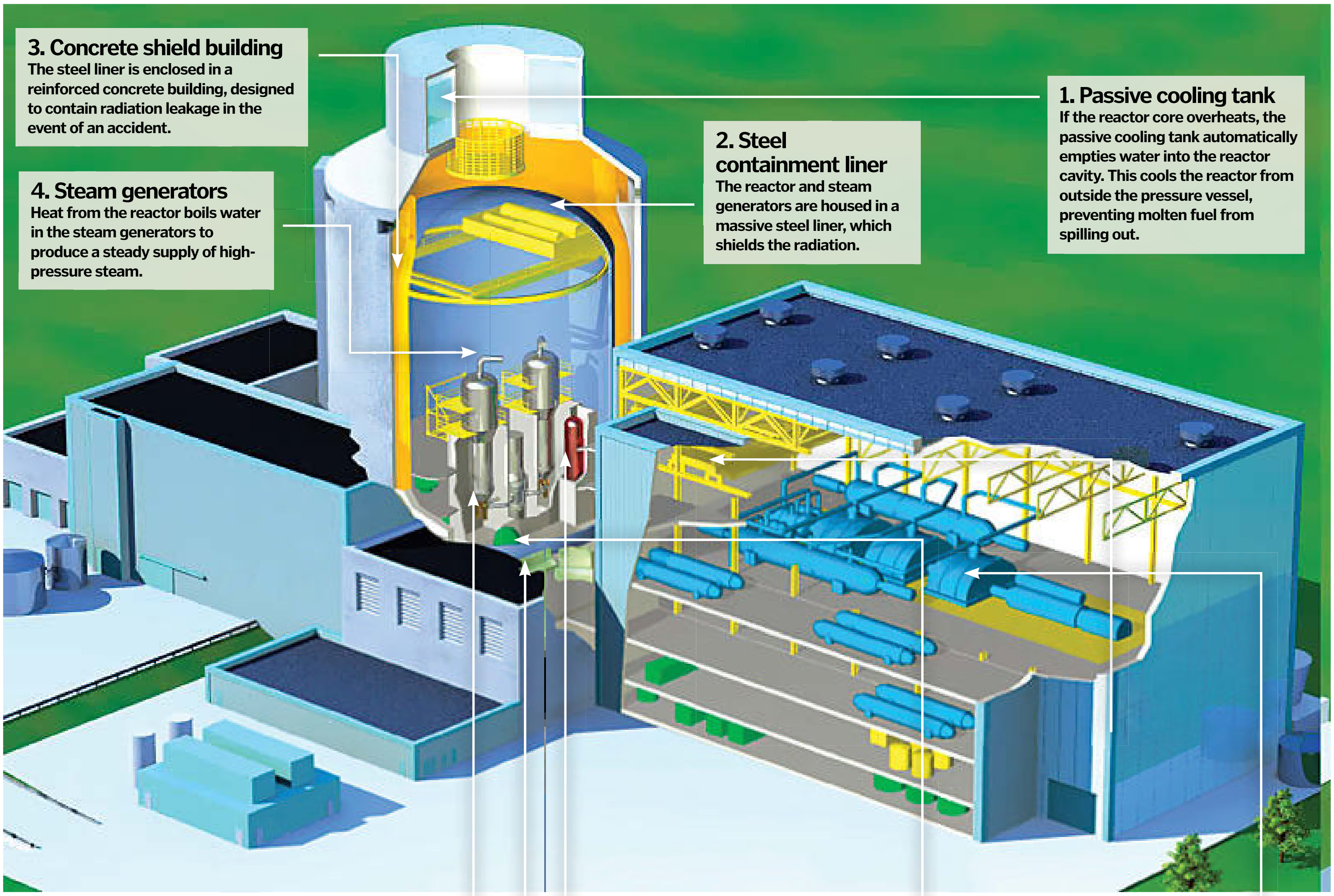
The rotational ability of the lamp was classically generated by a hand crank, which would be wound by the lighthouse keeper up to every two hours. In modern lighthouses the lamps are powered by diesel electric generators.

Tower

Lighthouse towers are usually either built onshore or directly on the seabed. This is best shown in the caisson method, where an open-ended cylinder is sunk and filled with concrete to form a solid base. However the latter is less common due to the erosion suffered by sea waves. Towers have a distinctive shape and colour – often a top-tapered, white tower – to help sailors identify it. Within the tower it is also common to find the lighthouse's service room, the place where the fuel/generator is kept.

Gallery

The gallery is the lighthouse's circular, external platform that is often wrapped around one or two levels. It is used for human observation and also as a maintenance platform for cleaning the lantern room's windows.



1. Passive cooling tank
If the reactor core overheats, the passive cooling tank automatically empties water into the reactor cavity. This cools the reactor from outside the pressure vessel, preventing molten fuel from spilling out.

2. Steel containment liner
The reactor and steam generators are housed in a massive steel liner, which shields the radiation.

3. Concrete shield building
The steel liner is enclosed in a reinforced concrete building, designed to contain radiation leakage in the event of an accident.

4. Steam generators
Heat from the reactor boils water in the steam generators to produce a steady supply of high-pressure steam.

5. Pressuriser
Operators control the pressure of the coolant water around the reactor by adjusting the air level in the pressuriser.

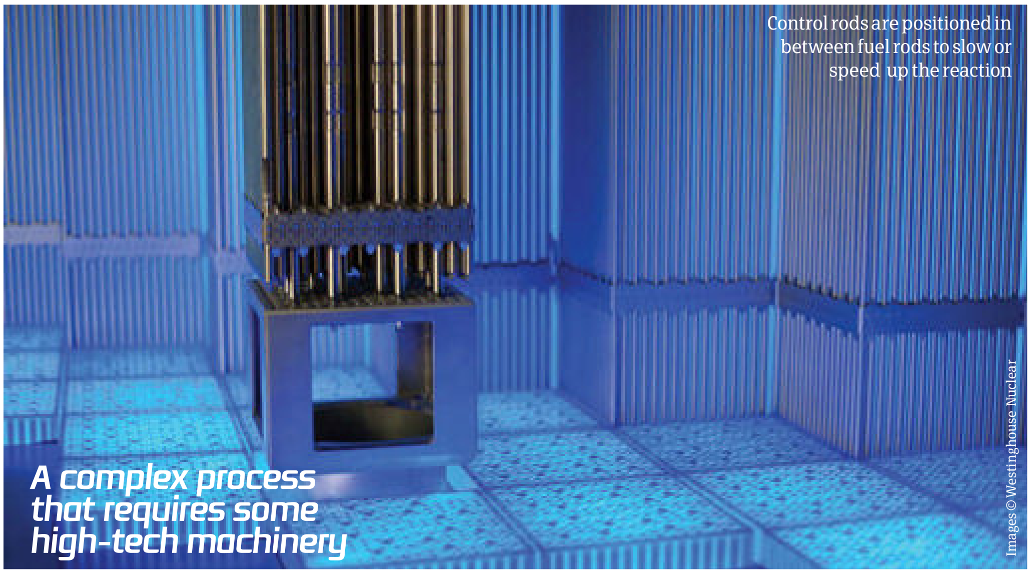
6. Reactor coolant pumps
Pumps constantly circulate water to cool the reactor and transfer heat to the steam generators.

7. Main control room
Operators monitor and control reactor activity from a central control room.

8. Reactor
The reactor comprises the uranium fuel rods and control rods, housed in a steel containment vessel.

9. Turbine generator
Steam from the steam generator spins a turbine, which powers an electric generator.

Inside a nuclear power station



Control rods are positioned in between fuel rods to slow or speed up the reaction

A complex process that requires some high-tech machinery

Images © Westinghouse Nuclear

5 TOP FACTS NUCLEAR POWER

A global energy source
1 Nuclear power provides 15 per cent of the world's electricity. That power comes from 436 reactors that are in operation worldwide.

Born in the USA
2 The very first nuclear reactor, built in Arco, Idaho in 1951, only powered four light bulbs. It was known as the Nuclear Reactor Testing Station.

A lot of waste
3 The yearly total of waste that is produced from nuclear power is somewhere between 8,800 and 13,200 tons – that's a lot of waste!

Powers most of France
4 A total of 59 reactors provide 76 per cent of France's electricity, compared to the UK's 24 reactors providing 19 per cent of our electricity.

It's out to sea
5 Approximately 150 ships, ranging from huge submarines to massive aircraft carriers, are powered by nuclear reactors.

DID YOU KNOW? A single pound of enriched uranium can provide the same energy as 3 million pounds of coal

From fission to electricity

The principles of nuclear power are remarkably simple. Here's how a pressurised water reactor station turns subatomic particle activity into usable power

1. Fuel rods
Hundreds of 3.6m uranium rods undergo a fission reaction, releasing substantial heat.

2. Reactor
A steel pressure vessel contains the uranium rods, surrounding water and other reactor components.

3. Control rods
Operators can speed up or slow down the fission reaction by raising and lowering neutron-absorbing rods between the fuel rods.

4. Pump
A water pump keeps water circulating, and transfers heat away from the reactor core.

5. Pressuriser
The pressuriser contains water, air, and steam. By adding or releasing air in the pressuriser, operators can control the pressure of the coolant water around the reactor.

6. Heat exchanger
A pipe carries hot water from the reactor to a separate reservoir of water.

7. Steam generator
The hot pipe leading from the reactor heats a separate reservoir of water to the boiling point, generating steam.

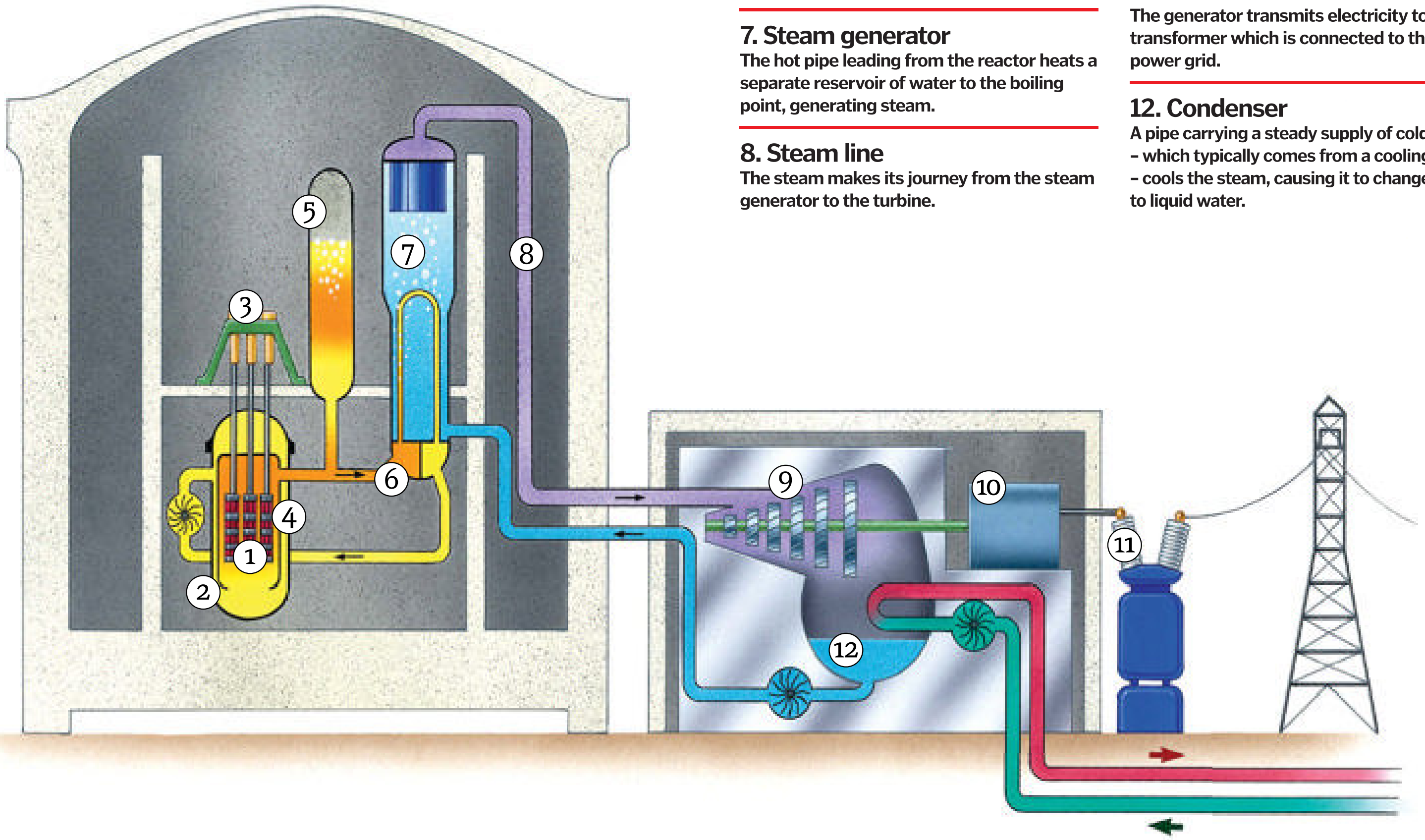
8. Steam line
The steam makes its journey from the steam generator to the turbine.

9. Turbine
Rushing steam drives the turbine which in turn powers the generator.

10. Generator
The turbine spins a rotor that sits in a magnetic field in a generator, inducing an electric current.

11. Transformer
The generator transmits electricity to a transformer which is connected to the power grid.

12. Condenser
A pipe carrying a steady supply of cold water – which typically comes from a cooling tower – cools the steam, causing it to change back to liquid water.



Images © DK Images

Ecological saviour or a looming catastrophe?

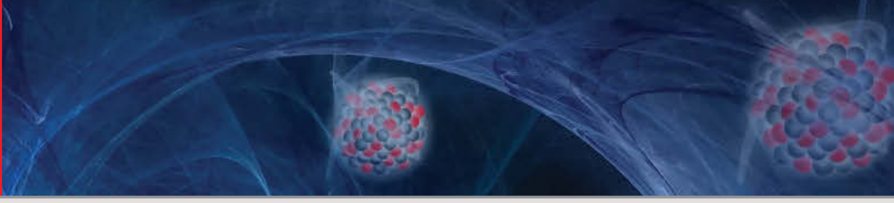
After the Three Mile Island meltdown in 1979, the Chernobyl catastrophe in 1986, and the Fukushima disaster of 2011, nuclear power found itself on the environmental villains list. And yet in the face of mounting global warming concerns, it remains a marvel. Since nuclear power produces no greenhouse gasses, proponents are touting it as a greener alternative to fossil fuels. They argue that one pound of enriched uranium (the chief nuclear fuel) can provide the same energy as 3 million pounds of coal or 1 million gallons of gasoline.

But there's a catch. Nuclear fuel produces radioactive waste, which can cause cancer, trigger birth defects, and spawn mutants. The technology is both fascinating and ominous and you're about to find out why.

Nuclear power plants are complexes that span many square kilometres, but the real action happens on a subatomic level. The sole purpose of a plant is to harness the energy of nuclear fission – a reaction where an atom's nucleus splits into two smaller nuclei.

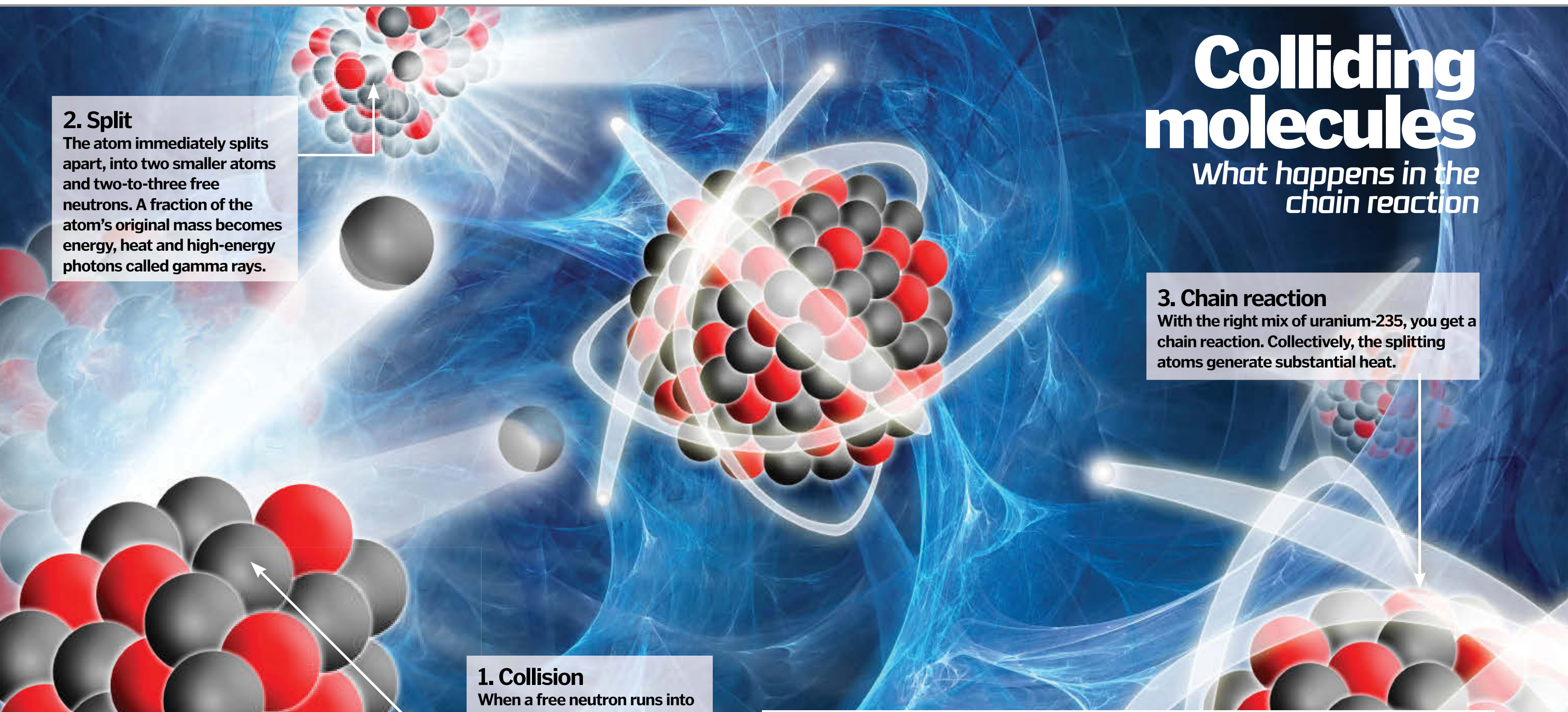
Specifically, nuclear plants typically derive power from inducing nuclear fission in enriched uranium oxide, comprising 96-97 per cent uranium-238 and three-to-four per cent uranium-235. Uranium is the heaviest of all natural elements and one of the easiest to break apart. When a relatively slow-moving free neutron runs into a uranium-235 atom, the atom will absorb the neutron, and the extra energy will make the atom unstable. The atom immediately splits apart, into two smaller atoms and two-to-three free neutrons. A fraction of the atom's original mass becomes energy, in the form of heat and high-energy photons called gamma rays.

With the right mix or uranium-235, you get a chain reaction. Some of the free neutrons generated in the fission reaction encounter other uranium-235 ▶



Colliding molecules

What happens in the chain reaction



2. Split
The atom immediately splits apart, into two smaller atoms and two-to-three free neutrons. A fraction of the atom's original mass becomes energy, heat and high-energy photons called gamma rays.

3. Chain reaction
With the right mix of uranium-235, you get a chain reaction. Collectively, the splitting atoms generate substantial heat.

1. Collision
When a free neutron runs into a uranium-235 atom, the atom will absorb the neutron, and the extra energy will make the atom unstable.

▶ atoms, causing those atoms to split apart, producing more free neutrons. Collectively, the splitting atoms generate a substantial heat. All the equipment in a nuclear plant has one core function: safely harnessing this heat to generate electricity.

The heart of a nuclear power plant is the reactor, which contains the uranium fuel and the equipment that controls the nuclear fission reaction. The central elements in the reactor are 150-200 bundles of 3.6m-long fuel rods. Each bundle includes 200-300 individual rods, which are made from small uranium oxide pellets. The rods are immersed in a coolant and housed in a steel pressure vessel.

The fission reaction continues indefinitely when, on average, more than one neutron from each fission reaction encounters another uranium atom. This state is called supercriticality. In order to safely heat the water, the reactor must keep the fuel slightly supercritical, without allowing a runaway fission reaction.

The key mechanism for controlling the reaction rate are a series of control rods, made from neutron-absorbing material such as cadmium. Operators can move the control rods in and out of the bundles of uranium rods. To slow down the fission reaction, operators lower the rods into the bundles. The rods absorb neutrons from the fission reactions, preventing them from splitting additional nuclei. Operators can stop the fission reaction by lowering the control rods all the way into the uranium rod bundle. To accelerate the fission reactions, operators partially raise the rods out of the bundle. This increases the rate of free neutrons colliding with uranium atoms to keep the fission reaction going.

Apart from the fission reaction, a nuclear plant works the same basic way as a coal-burning plant: the fuel

> "The heart of a nuclear power plant is the reactor"

The concrete and steel sarcophagus erected around the damaged reactor at Chernobyl

When nuclear reactors fail

From Fukushima to Chernobyl, the risks that accompany nuclear power production are real

When a magnitude nine earthquake shook Japan in March 2011, the water stopped circulating at the Boiling Water Reactor (BWR) station in Fukushima and a build up of hydrogen gas blew the roof off the building. The fear of a radiation leak occurred when the coolant water (which immerses the fuel rods) failed and exposed the fuel elements in the reactor vessel to air. In case of an emergency the control rods slide in between the fuel elements to halt the nuclear reaction process, but if the fuel elements are not cooled there can still be a risk of radiation leaking. Technicians used seawater to attempt to cool the fuel rods.

And 25 years after reactor four at the Chernobyl Nuclear Power Plant exploded, we're still reminded of the risk posed by nuclear power. Chernobyl's reactors had little shielding to protect against radioactive contamination and the blasted reactor burned for ten days, spewing 400 times the radioactive fallout that fell on Hiroshima in the World War II bombing. The explosion and radiation exposure killed 56 people soon after the blast, but the total death toll is impossible to calculate, due to the contamination's far reach and long-term effects.

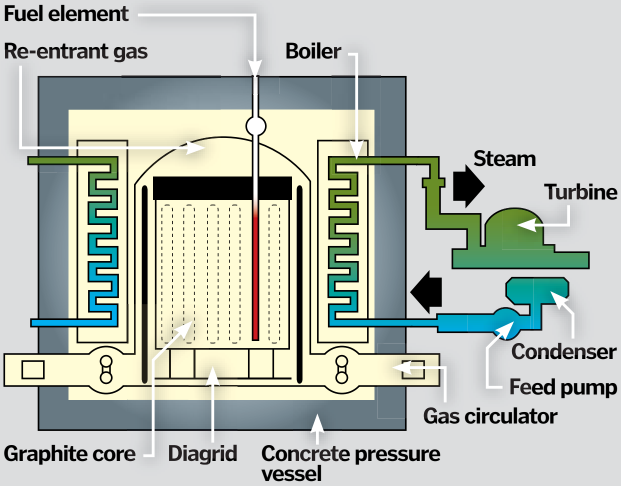
DID YOU KNOW? *Radioactive rain resulting from the Chernobyl disaster reached as far as Ireland*

Types of reactor

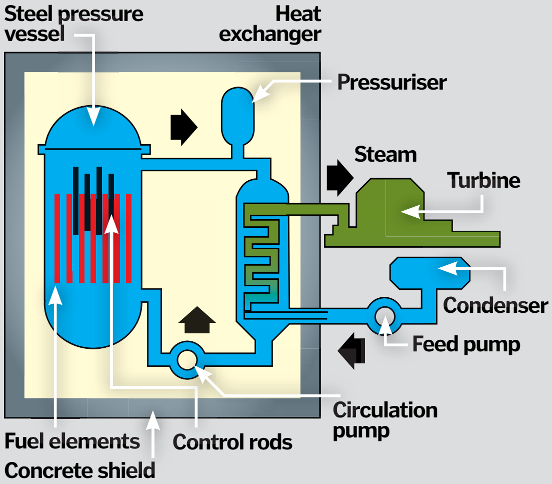
Several nuclear reactor designs are in operation today

The most common design is the pressurised water reactor (PWR). PWRs use pressurised water both as a moderator (the material that slows down free neutrons, increasing the rate of fission reactions) and as a coolant (the substance that transfers heat away from the reactor core to the steam generator). Another common design, the advanced gas-cooled reactor, uses graphite as a moderator and carbon dioxide as a coolant. The chief advantage of this design is that it's possible to heat carbon dioxide to higher temperatures than water (about 650°C vs 325°C). The greater heat capacity greatly improves plant efficiency.

Advanced gas-cooled reactor (AGR)



Pressurised water reactor (PWR)



generates heat, which boils water, which produces steam, which turns a turbine, which drives an electric generator.

In a pressurised water reactor, the heat from fission doesn't produce steam directly. The fission reaction heats the water inside the pressure vessel to about 325 degrees Celsius, but the water is kept under high pressure to keep it from boiling. A pumping system drives this hot water through a pipe that runs to a separate water reservoir, in the steam generator. The pipe heats the water in the steam generator to the boiling point, and it produces steam. The rushing steam turns a turbine and then reaches a cooling system. As the steam cools, it condenses back into a liquid. The liquid water returns to the reservoir, and boils again, repeating the cycle. As the turbine spins, it powers a generator, which produces an electric current. And there you have it: usable electric power.

Nuclear fission produces high levels of gamma and beta radiation, which can mutate cells, causing cancer and birth defects, among other things. Naturally, the most important concern when designing a nuclear power plant is containing this dangerous radiation.

A modern nuclear power plant has many layers of protection. The pressure vessel that contains the uranium rods is encased in a thick concrete liner, which blocks gamma radiation. The entire reactor and the steam generator system are housed in a giant steel liner, providing additional radioactive shielding. The steel liner is surrounded by an outer concrete structure, designed to contain the radiation, even in the event of an earthquake. Modern nuclear power plants also include advanced automatic cooling systems, which kick into action in the event of the reactor or other equipment overheating.

The spent uranium rods are also highly radioactive, which means power plants can't just throw them away. The best solutions anyone has come up with so far is to encase the nuclear waste in massive concrete and steel structures or bury it underground.

The water treatment systems in a power plant

Jean Paul Gaultier's new winter line received a mixed reaction

Pros and cons

The most powerful force ever harnessed by mankind

The remarkable advantage of nuclear power plants is they generate electricity without emitting any air pollution. The clouds billowing from cooling towers are nothing but harmless steam.

Nuclear power does take a toll on the environment, however. Mining uranium destroys natural habitats, and the activity involved in both mining and processing uranium produces greenhouse gasses.

The bigger problem is fuel radioactivity. As Chernobyl demonstrated, accidents can cause widespread disease. Nuclear waste remains highly radioactive for thousands of years, and there's already more than 60,000 metric tons of it to deal with. Nobody wants it in their backyard. Another concern is waste falling into the wrong hands, giving terrorists material for weapons.

In recent years, dozens of nations have decided the benefits are worth the risks and are forging ahead. They're touting nuclear power as the way of the future – just as it was 60 years ago.

Learn more

For more information about the Chernobyl disaster, head to **www.world-nuclear.org/info/chernobyl/inf07.html** where you can read an in-depth analysis of the events and impact relating to the unfortunate catastrophe in Ukraine.

> "Recoil is the gun's kick-back, balancing the bullet's forward momentum"

How do semi-automatic pistols work?

The colourful profile of the semi-automatic weapon continues to shape public opinion, but there is more to its substance than style alone

The semi-automatic pistol is a functionally different animal to the romanticised revolver of the Wild West. The motivation for semi – and full for that matter – automatics derive from energy generated by the firing process to self-load and prime a new round. This comes in a variety of flavours, including recoil, blowback and gas.

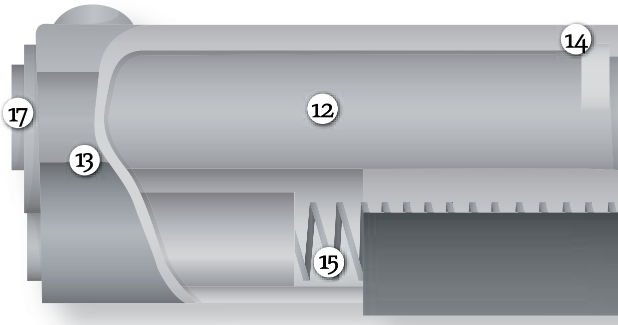
Recoil is the gun's kick-back, balancing the bullet's forward momentum – or as Newton says, with every action must come an equal and opposite reaction. Here, the opposing recoil force drives the gun backwards, initiating momentum in the 'slide' and barrel that are mechanically engaged. Separation of the two typically allows the breech to open as the slide carries on, self-loading and cocking the gun in the process.

With blowback the barrel and slide are not wed. The barrel is typically fixed to the frame with the shunting force of the exploding cartridge operating against the breech face itself and forcing the slide to the rear. The infamous AK-47 is a further example of a system that siphons gas drawn from the fired cartridge explosion to cycle the self-loading process.

Despite these distinctions, the term automatic is often clouded with reference to loading and firing. Though its function is distinct from its ancestors, the triggering mechanism of semi-automatics such as the US Army's M1911 mean they can only discharge one round for every reciprocal pull of the trigger. This differentiates them from full automatics which utilise a trigger mechanism that actuates a continuous self-loading/firing cycle until a gun's clip is spent or trigger released.

Due to the unwieldy nature of full automatic pistols, semi-automatic variants are now common throughout the military, police and criminal underworld.

Firearms training makes for better, safer shooters

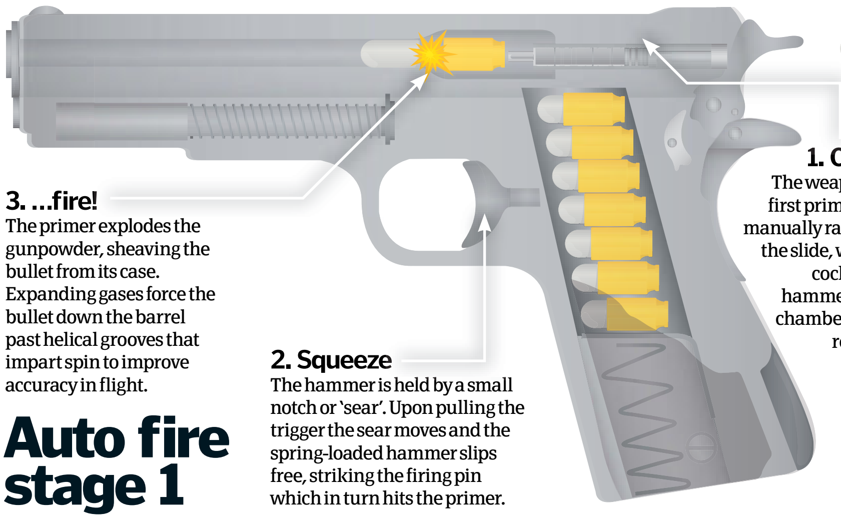


Inside a semi-automatic

There are many components inside these pistols

Pistol key:

1	Single action (SA) trigger/ double action (DA) trigger
2	Disconnector (engaged in semi-automatics)
3	Sear
4	Safety grip (must be depressed or gun will not fire)
5	Magazine/Magazine spring (holds upwards of 15 rounds or more)
6	Centerfire cartridge
7	Hammer
8	Firing pin
9	Breech
10	Extractor
11	Chamber
12	Barrel rifling
13	Slide
14	Top locking lugs
15	Recoil spring
16	Link
17	Muzzle

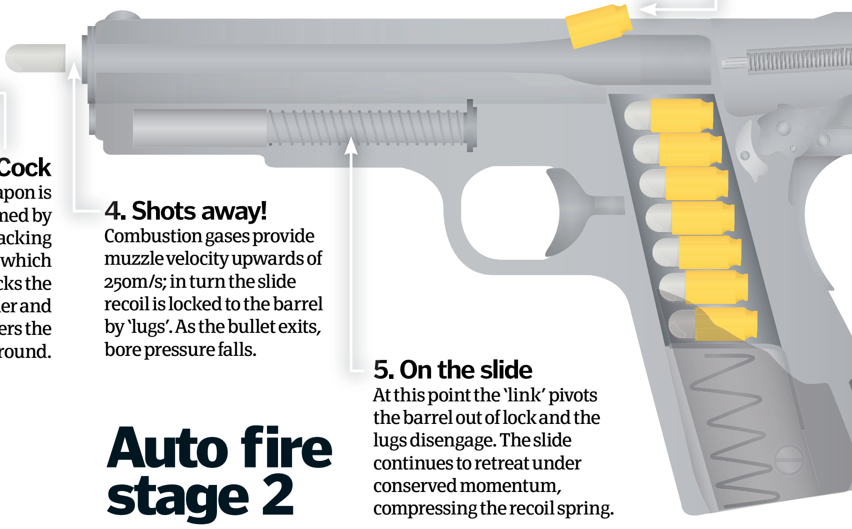


Auto fire stage 1

1. Cock
The weapon is first primed by manually racking the slide, which cocks the hammer and chambers the round.

2. Squeeze
The hammer is held by a small notch or 'sear'. Upon pulling the trigger the sear moves and the spring-loaded hammer slips free, striking the firing pin which in turn hits the primer.

3. …fire!
The primer explodes the gunpowder, sheaving the bullet from its case. Expanding gases force the bullet down the barrel past helical grooves that impart spin to improve accuracy in flight.



Auto fire stage 2

4. Shots away!
Combustion gases provide muzzle velocity upwards of 250m/s; in turn the slide recoil is locked to the barrel by 'lugs'. As the bullet exits, bore pressure falls.

5. On the slide
At this point the 'link' pivots the barrel out of lock and the lugs disengage. The slide continues to retreat under conserved momentum, compressing the recoil spring.

6. Up and out
The breech opens, the extractor and ejector take turns to draw and kick out the spent chambered cartridge. The slide continues passing over and recocking the hammer.

5 TOP FACTS TYPES OF GUN

Lever-action

1 Synonymous with the Winchester Rifle, this action allowed the likes of Billy the Kid to lever new rounds from a sealed tubular magazine, all in one movement.

Giving it both barrels

2 The double-barrelled shotgun is the prime example of 'break-open' in action; whereby barrels are hinged to expose the breech and ready new rounds.

2,000 rounds a minute

3 Gatling's gun housed upwards of ten barrels, each with its own breech and firing pin, loaded upon cranked rotation by a gravity-fed ammunition hopper.

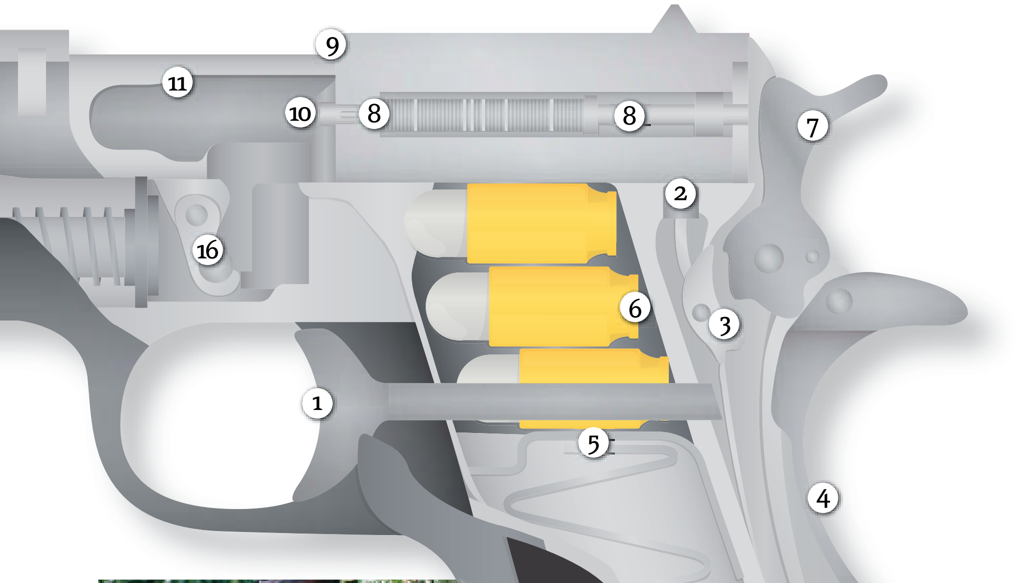
Unchained melody

4 The chain gun has a single barrel and employs an electric motor to drive a chain that is connected to the bolt, which moves back and forth to reload the weapon.

Pump up the volume!

5 The pump-action is most often found in repeating rifles and shotguns; with a hand grip that is pumped back and forth that strips the spent shell and loads a fresh round.

DID YOU KNOW? *Holding a full automatic on its side helps against the potential for kick up and vertical spray*



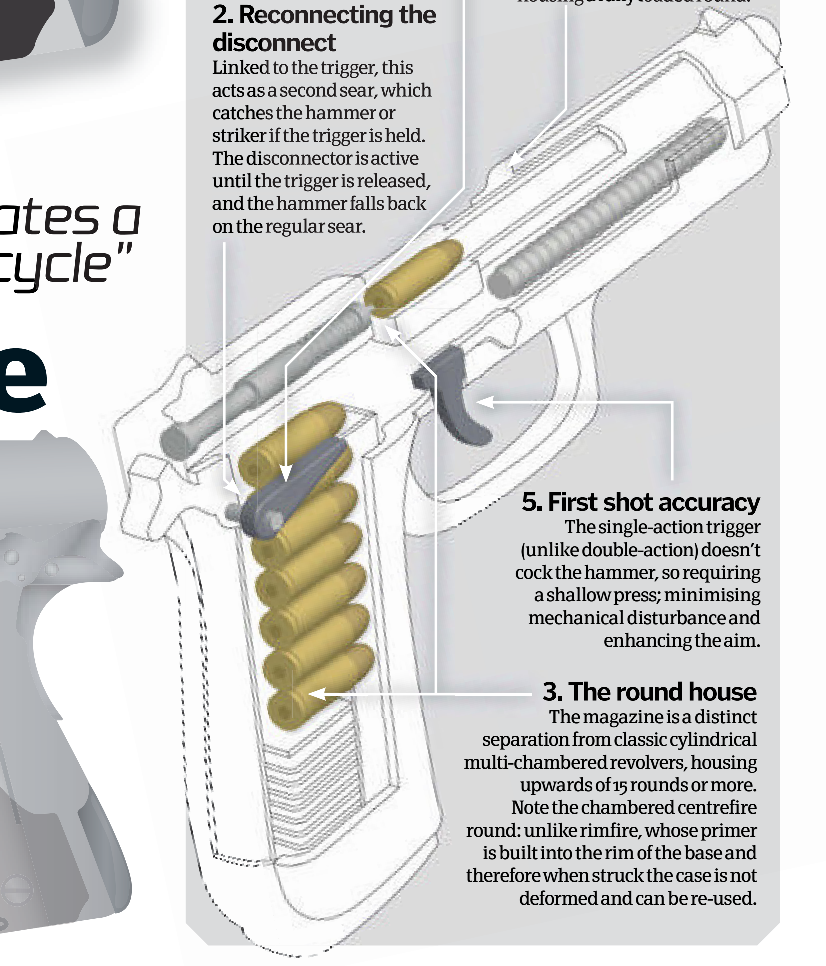
Taking cover.... along with you

Semi vs fully automatic

While both loading mechanisms are automated, the advantage of going full automatic means there is no trigger disconnect and no mechanical delay in the cycling of fire representative of semi-automatic weapons. Therefore, while they are great in a tight spot and satisfy a penchant for wanton carnage, such continuous fire – allied to a typically low weight and no shoulder stock – makes them tough to control, and a tendency to kick-up during firing makes them prone to vertical spray.

'Cook-off' is also a factor in full automatics, where a round may dispense prematurely from the over-heated chamber. Full automatics often benefit from an open bolt policy, where the slide is held back at the end of the cycle to allow cooling air to filter the barrel.

Another issue is slam fire. This occurs when the slide is released and the force of it closing is powerful enough to detonate the primer. They are also subject to jamming, where the cartridge can stick while entering, or ejecting from the chamber.



1. Safety first

With frame-mounted safety locking, the hammer and slide allow the gun to be carried with hammer in a "cocked and locked" state.

2. Reconnecting the disconnect

Linked to the trigger, this acts as a second sear, which catches the hammer or striker if the trigger is held. The disconnector is active until the trigger is released, and the hammer falls back on the regular sear.

4. Closed-bolt design

Commonly seen in semi-automatics that are less prone to 'cook-off', but also found on full automatics. Once cocked, the slide is forward and breech closed, with the chamber housing a fully loaded round.

5. First shot accuracy

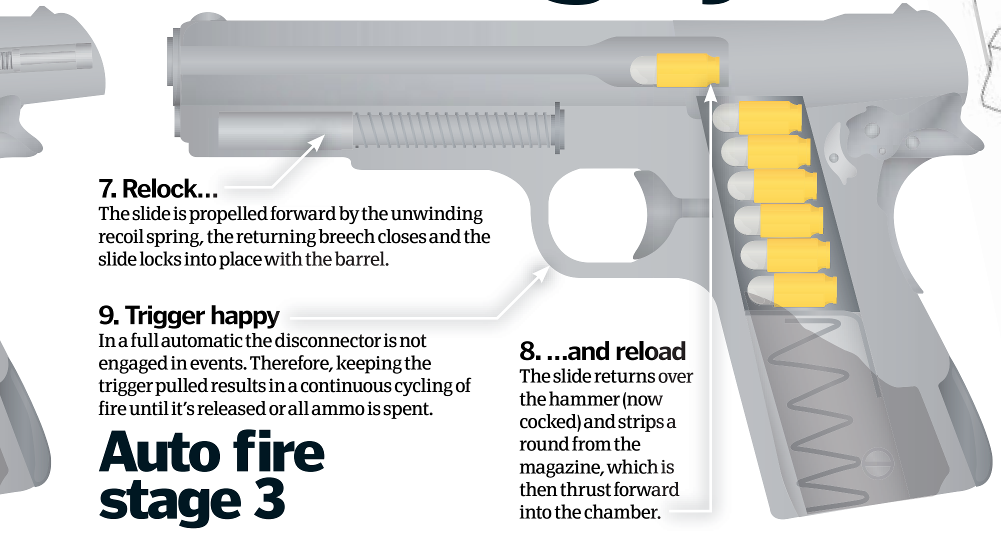
The single-action trigger (unlike double-action) doesn't cock the hammer, so requiring a shallow press; minimising mechanical disturbance and enhancing the aim.

3. The round house

The magazine is a distinct separation from classic cylindrical multi-chambered revolvers, housing upwards of 15 rounds or more. Note the chambered centrefire round: unlike rimfire, whose primer is built into the rim of the base and therefore when struck the case is not deformed and can be re-used.

> *"A trigger mechanism that actuates a continuous self-loading/firing cycle"*

The firing cycle



7. Relock...

The slide is propelled forward by the unwinding recoil spring, the returning breech closes and the slide locks into place with the barrel.

9. Trigger happy

In a full automatic the disconnector is not engaged in events. Therefore, keeping the trigger pulled results in a continuous cycling of fire until it's released or all ammo is spent.

8. ...and reload

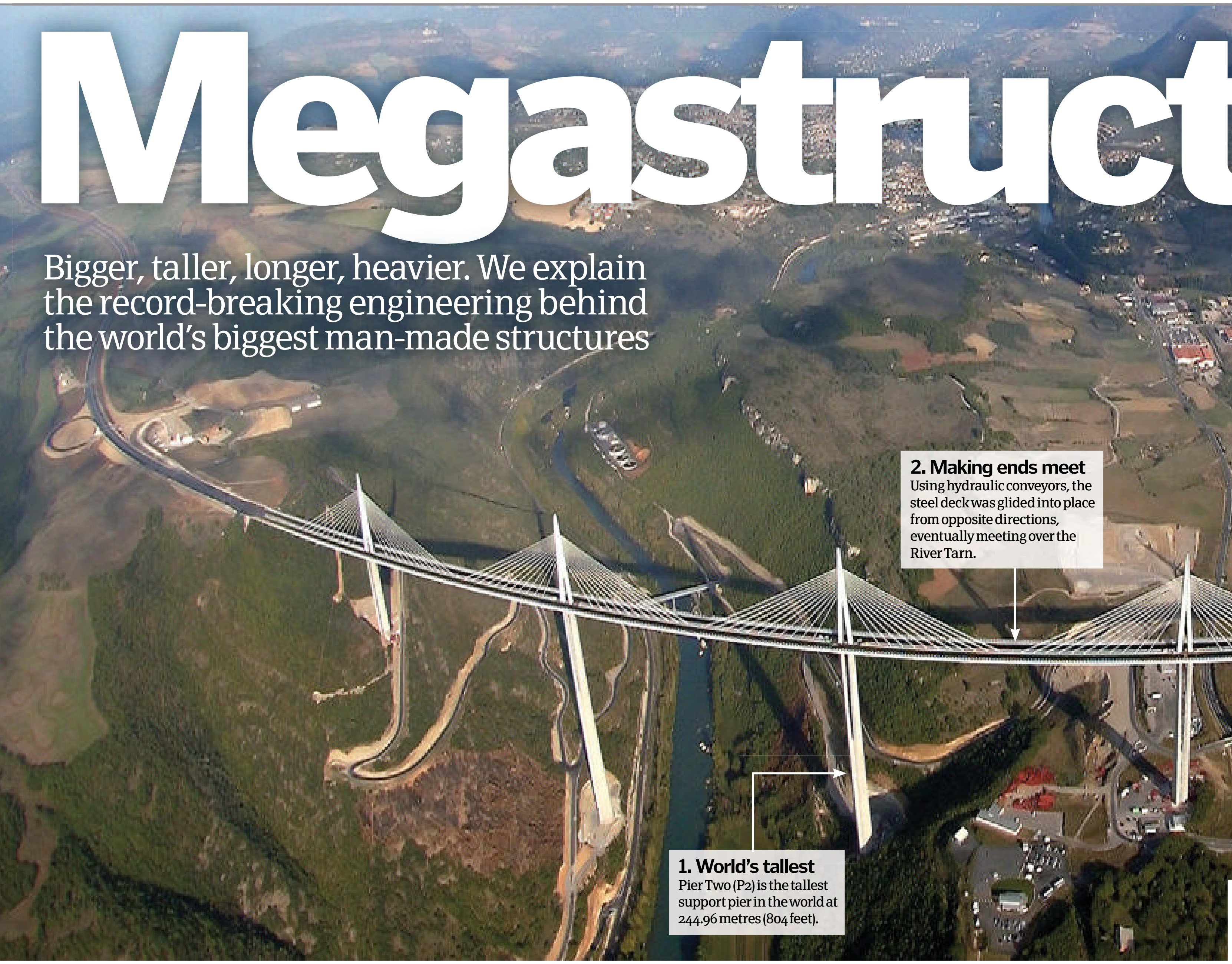
The slide returns over the hammer (now cocked) and strips a round from the magazine, which is then thrust forward into the chamber.

Auto fire stage 3

> "Up close the world's tallest bridge is no less stunning"

Megastruct

Bigger, taller, longer, heavier. We explain the record-breaking engineering behind the world's biggest man-made structures

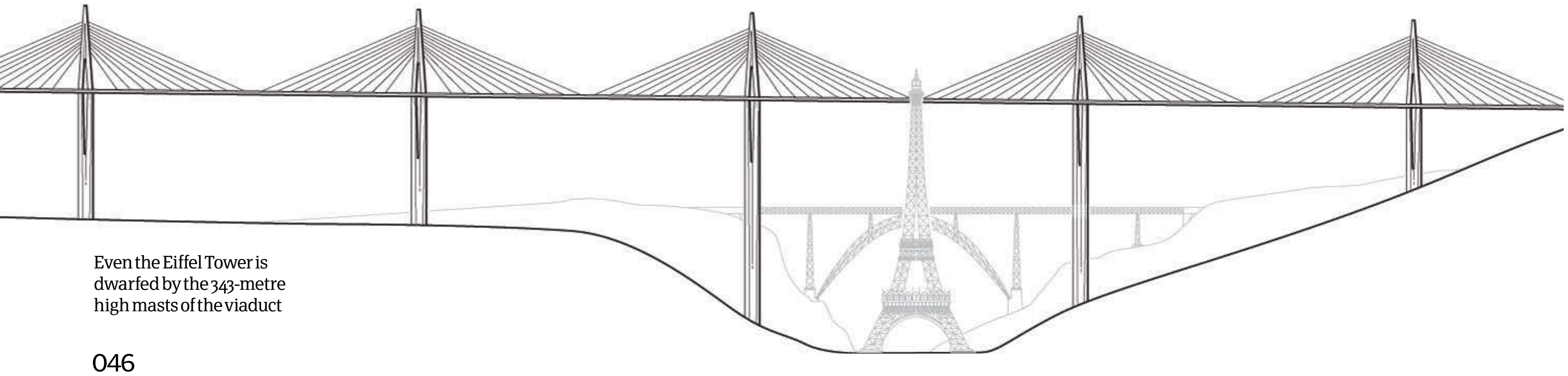


2. Making ends meet
Using hydraulic conveyors, the steel deck was glided into place from opposite directions, eventually meeting over the River Tarn.

1. World's tallest
Pier Two (P2) is the tallest support pier in the world at 244.96 metres (804 feet).

Since the reign of the pharaohs, the lure of the very large has proven irresistible to visionary architects and game-changing engineers. Ancient Egypt had its pyramids, the Chinese dynasties had their Great Wall and modern Dubai has its… well, pretty much everything. At the heart of every megastructure is a dare: how far can you go? And every few years or so, some ambitious billionaire ups the ante, going higher, longer, deeper and more wildly expensive.

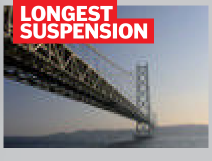
The 828-metre (2,717-foot) Burj Khalifa tower in Dubai makes your palms sweat just looking at pictures from the observation deck. And not to be outdone, Dubai's Palm Islands are visible from space with the naked eye. None of these mind-blowing projects would be possible without quantum leaps in structural engineering, materials science, construction technology and logistics. On these pages, we'll explain the extreme engineering behind extraordinary structures.



Even the Eiffel Tower is dwarfed by the 343-metre high masts of the viaduct

© Science Photo Library

Head to Head BRIDGES


LONGEST SUSPENSION

1. Akashi Kaikyo Bridge

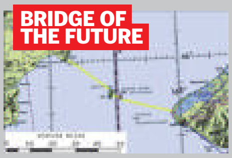
At 3,900 metres long, this masterwork of Japanese engineering can survive an earthquake up to 8.5 on the Richter scale.

© FXFOWLE

BIGGEST ARCH

2. Dubai's Mile-Long Bridge

Leave it to boomtown Dubai to dream up a fantastically futuristic proposal for a mile-long double arch bridge spanning 12 lanes of traffic.

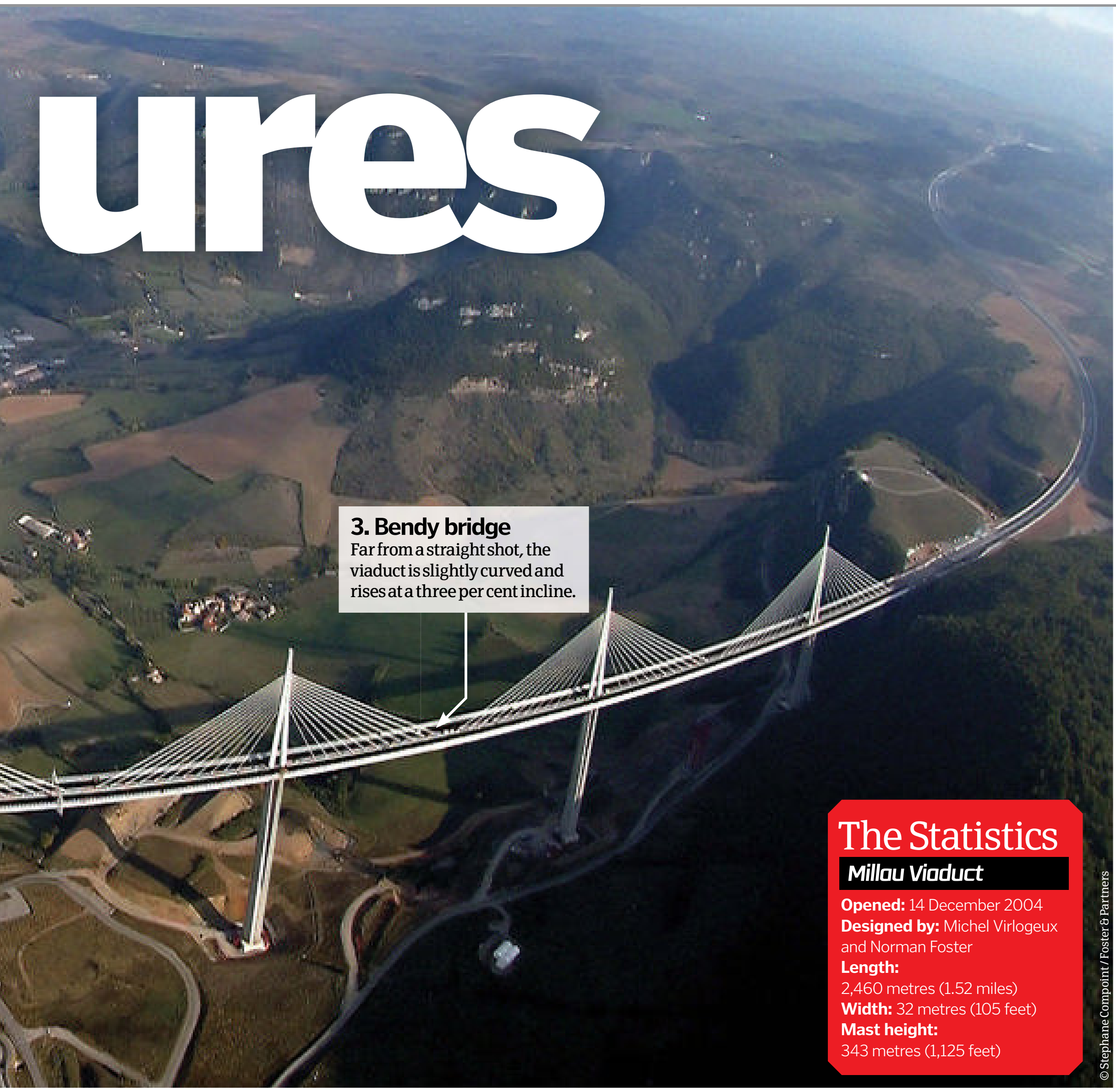

BRIDGE OF THE FUTURE

3. Bering Strait Bridge

The proposed 88.5km (55mi) bridge linking North America and Asia would carry vehicle traffic, a high-speed train and pipelines for natural gas and oil.

DID YOU KNOW? The Millau Viaduct was officially opened on 14 December 2004

ures

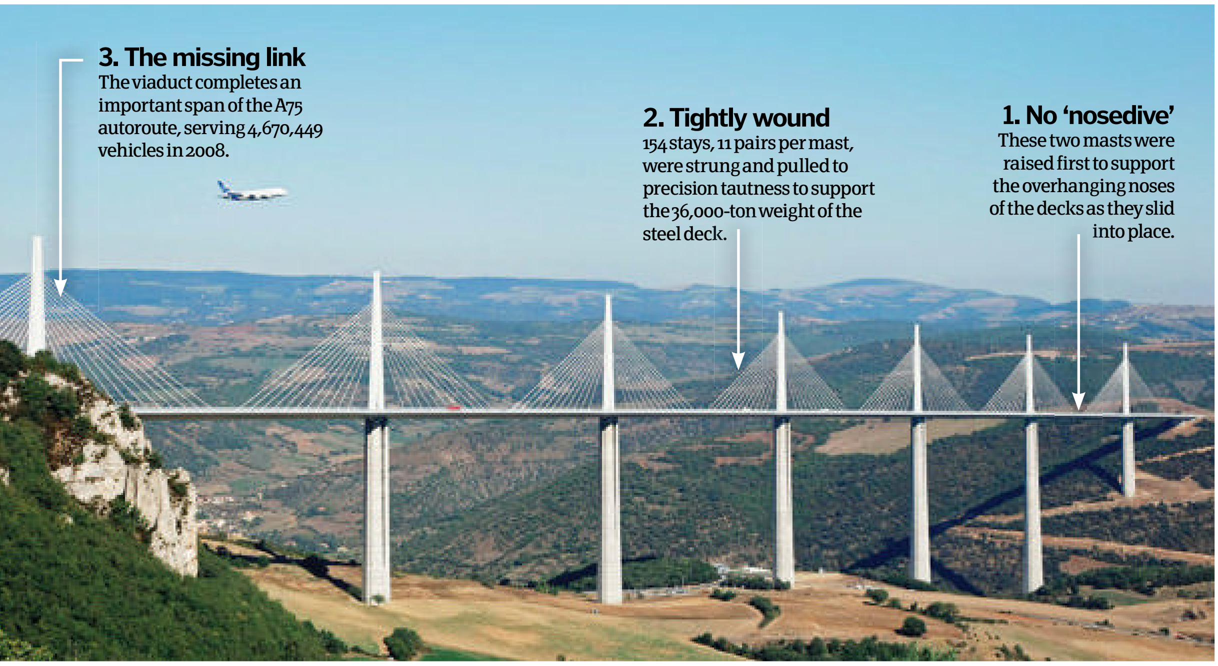

© Stephane Compoint / Foster & Partners

3. Bendy bridge
Far from a straight shot, the viaduct is slightly curved and rises at a three per cent incline.

The Statistics

Millau Viaduct

Opened: 14 December 2004
Designed by: Michel Virlogeux and Norman Foster
Length: 2,460 metres (1.52 miles)
Width: 32 metres (105 feet)
Mast height: 343 metres (1,125 feet)



3. The missing link
The viaduct completes an important span of the A75 autoroute, serving 4,670,449 vehicles in 2008.

2. Tightly wound
154 stays, 11 pairs per mast, were strung and pulled to precision tautness to support the 36,000-ton weight of the steel deck.

1. No 'nosedive'
These two masts were raised first to support the overhanging noses of the decks as they slid into place.

The Millau Viaduct

Majestic and minimalist, the world's longest bridge is also one of the most beautiful

From a distance, the seven steel masts of the record-breaking Millau Viaduct in southern France look like billowing sails of a cosmic spacecraft. Up close, the tallest bridge in the world is no less stunning, a minimalist masterpiece that resembles an Apple iPad in bridge form.

The Millau Viaduct is a cable-stayed road bridge of concrete and steel with load-bearing masts stretching 343 metres (1,125 feet) into the air. 17 years in the making – at a cost of 400 million euros – the 2,460-metre (1.52-mile) span employed the very latest construction techniques and technologies during each of its six stages of fabrication and assembly.

First came the 'legs' of the bridge, seven thick piers consisting of 206,000 tons of poured concrete. The smooth, seamless surface of each pier was achieved using a machine called a self-climbing framework. Powered by hydraulic lifters, the concrete framework rises upwards with the pier at a rate of three meters every three days. Pouring continuously, the piers rose from the valley floor, reaching their peak heights in ten months.

Next came the deck, built from 173 steel box beams forged in the Eiffel factory. Using two on-site metalworks, the steel floor was welded to the box beams to create 171-metre deck panels. The panels were then 'launched' from both sides of the bridge using 64 hydraulic conveyors positioned atop the piers and temporary steel crutches. The two sides of the deck literally slid towards each other at a rate of 60cm per push, equal to nine metres an hour. The two sides finally met on 28 May 2004 at 2:12pm.

The seven steel masts support 1,500 tons of steel stays attached at 11 paired points. Each stay consists of up to 91 bound steel cables and each cable is made from seven individual strands of steel. The stays are triply weatherproofed to avoid corrosion.

Before paving the road, workers used high-pressure blasters to scour the steel deck with millimetre-size ball bearings. Once all traces of rust were removed, special equipment laid a four-centimetre thick layer of tar thermosealed at 400°C, offering complete corrosion protection.

The bridge construction is guaranteed for 120 years and is continuously monitored for movements as small as a micrometre by dozens of fibre-optic sensors strung throughout the structure.

"A starter home begins at £1.3 million"

The Statistics

Palm Jumeirah

Nickname: The Eighth Wonder of the World
Opened/opening: Palm Jumeirah, the smallest island, was completed in 2006
Built by: Nakheel
Length: 5km (3.1mi)
Width: 5km (3.1mi)
Composition: 94 million m^3 of reclaimed sand; 7 million tons of quarried rock
Cost: £8.14 billion ($12.3 billion)

Extreme islands

Dubai re-creates 'The World' from an ocean of sand

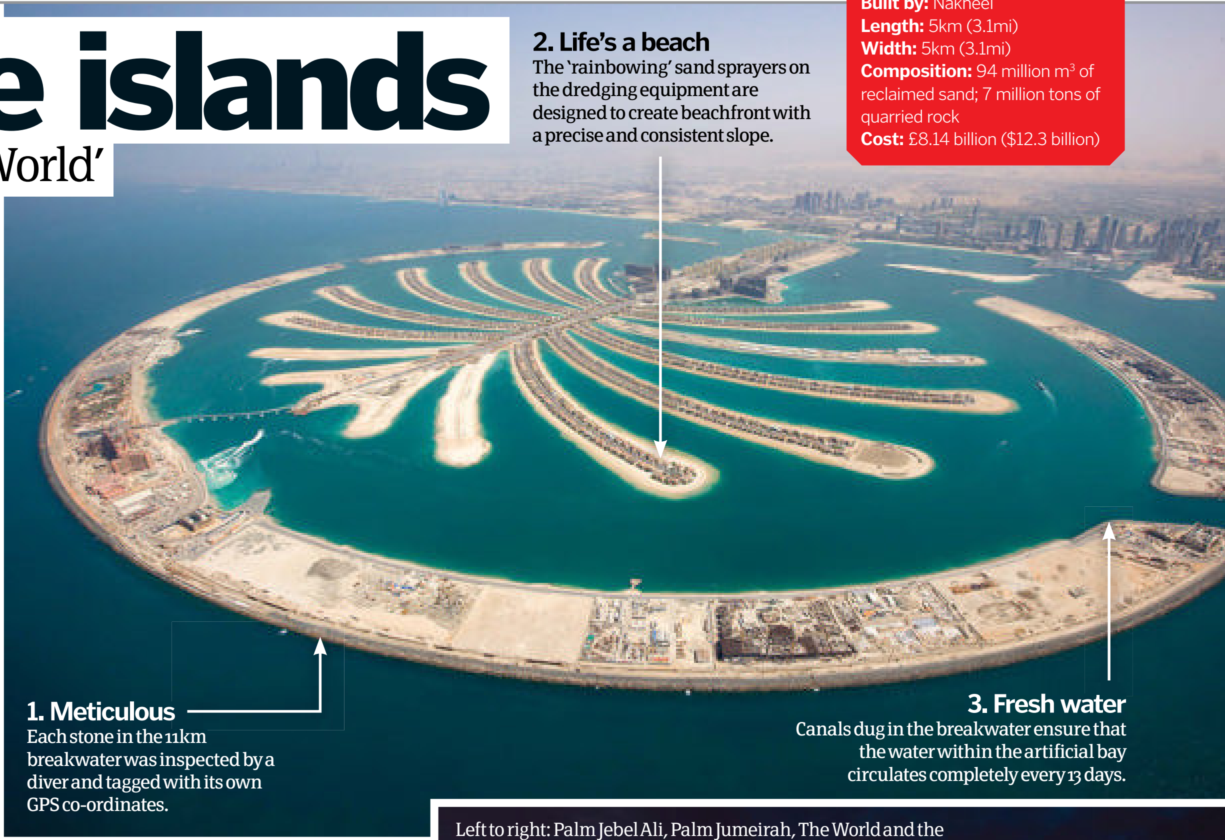
Sheikh Mohammed bin Rashid Al Maktoum has only one requirement for construction projects in his desert nation of Dubai: if it doesn't break a world record for tallest, biggest or most expensive, he's not interested. It shouldn't surprise, therefore, that the original design of the Palm islands – three man-made islands of colossal proportions off the coast of Dubai – came from the Sheikh's own pen.

But how do you build the world's largest man-made islands? Luckily, Dubai has almost as much sand as it does oil money. The state-run developer Nakheel hired the Dutch dredging firm Van Oord, specialists in land reclamation, to suction up millions of cubic metres of sand from the sea floor and precision spray it into the shape of a huge date tree with 16 slender fronds extending into the sea. Van Oord's dredging equipment is guided by DGPS (differential global positioning system), NASA's new real-time positioning technology that's accurate down to ten centimetres.

The first stage of each of Dubai's artificial island projects – the three Palm islands, plus a 300-island cluster in the shape of the continents called The World – is to install an artificial barrier reef as a water break. The artificial wall for The World, consisting of 34 million tons of carefully stacked rocks, is 27km long. The dredging team then builds each island or peninsula in stages, using heavier machinery for the island foundations and 'rainbowing' sand sprayers to finish the above-water detail work.

To prevent erosion, the base of the islands is reinforced with a layer of geotextile fabric that absorbs the impact of waves. The huge piles of loose sand are also treated to vibrocompaction, a process that uses water saturation and high-intensity vibrations to 'densify' the soil structure.

When complete, the Palm islands and The World will upgrade Dubai's beachfront property from a 37-mile stretch of condo-clogged real estate to 600 miles of pristine sand. In case you're wondering, a starter home on the smallest island starts at £1.3 million ($1.9 million).



2. Life's a beach
The 'rainbowing' sand sprayers on the dredging equipment are designed to create beachfront with a precise and consistent slope.

1. Meticulous
Each stone in the 11km breakwater was inspected by a diver and tagged with its own GPS co-ordinates.

3. Fresh water
Canals dug in the breakwater ensure that the water within the artificial bay circulates completely every 13 days.

Left to right: Palm Jebel Ali, Palm Jumeirah, The World and the early stages of Palm Deira, the largest of the artificial islands

Laerdal Tunnel

An ambitious dig gives drivers an unprecedented journey through the centre of the Earth

A decade ago, the drive from Oslo to Bergen, Norway required travellers to ferry multiple fjords and summit 1,600-metre peaks subject to rockslides and piles of snow. In 2000, King Harald V cut the ribbon on the Laerdal Tunnel, a 24.5km (15.2-mile) passage beneath the mountain ranges and waterways that had made travel between the two coastal cities so daunting and slow. Laerdal is by far the longest road tunnel in the world, beating the previous record-holder by seven kilometres.

Over five years, workers excavated 2.5 million cubic metres of rock. The tools of the trade were explosives and satellite-guided drilling jumbos. The blasting crew executed over 5,000 precision explosions each requiring 100 individually drilled holes, 5.2 metres deep, filled with an explosive called Anolit. Drilling rigs were guided by satellite positioning and on-board laser beams. Without this technology, it would have been impossible for the two excavation teams to meet each other over 10km inside the heart of the mountains.

To break up the monotony of the 20-minute subterranean drive, engineers divided the tunnel into four distinct sections separated by three wide, blue-lit caverns that give the sensation of an artificial sunrise.

The nine-metre tunnel widens considerably in the cavernous relief areas, providing room for vehicles to turn around. The tunnel is equipped with 48 additional emergency pull-offs

A blue-lit 'relief area' breaks up the mind-numbing monotony and creeping claustrophobia of a 20-minute drive through solid rock

5 TOP FACTS GIANT STRUCTURES

Great Wall of China
1 The original megastructure, the Great Wall stretches an incredible 8,851km (5,500 miles), making it easily the longest man-made structure on Earth.

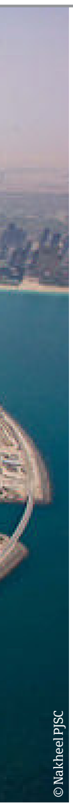
Three Gorges Dam
2 The 2km dam spanning the Yangtze submerged 13 existing cities, 140 towns and over 1,300 villages, requiring the relocation of 1.5 million people.

Fresh Kills Landfill
3 This retired garbage dump covering 12 square kilometres (4.6 square miles) of New York's Staten Island was once piled higher than the nearby Statue of Liberty.

Banaue Rice Terraces
4 Built largely by hand over 2,000 years ago, these terraced rice paddies cover 10,360 square kilometres of steep mountainside in the Philippines.

Mirny Diamond Mine
5 This colossal open-pit mine located in Eastern Siberia, Russia is 525 metres (1,722 feet) deep and 1.25km wide. In the Sixties it produced two tons of diamonds per year.

DID YOU KNOW? *Taipei 101 cost approximately $1.8 billion to build*


© Nakheel PJSC

© Nakheel PJSC

Taipei 101

The world's second-tallest skyscraper has a 660-ton pendulum for a heart

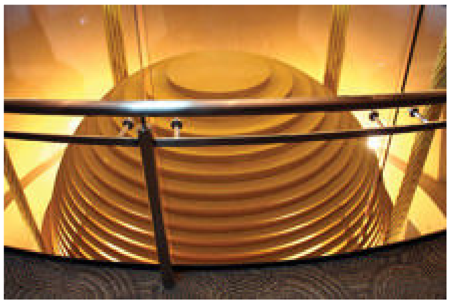
Building a skyscraper in Taipei is like playing Jenga on a trampoline. The Taiwanese capital, located along the famed Ring of Fire, sits atop an active seismological zone with a very long history of deadly earthquakes. As recently as 1999, a 7.3 trembler killed over 2,400 people. As if the earthquakes aren't enough, Taipei is also directly in the path of 26 annual tropical storms and typhoons, the Pacific equivalent of hurricanes.

Why would anyone attempt to build the world's tallest building on such shaky (and blustery) ground? You obviously don't know many engineers. The challenge of building a 508-metre megastructure in such an inhospitable location calls for elegant and ingenious solutions, two words that accurately describe Taipei 101, the 101-storey superscraper that was – until the completion of the Burj Khalifa in Dubai – the tallest man-made structure in the world.

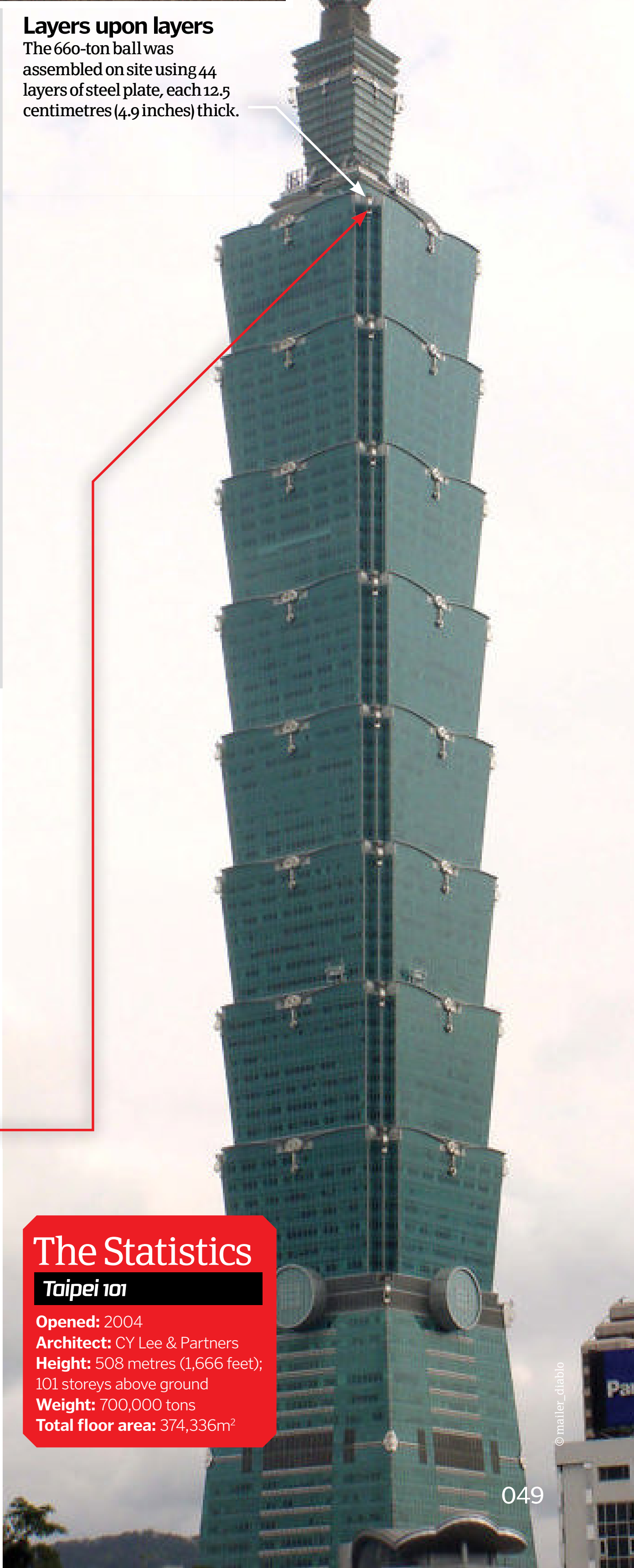
Taipei 101 was designed to resemble a bamboo shoot, rising upwards in eight sections (a lucky number in Chinese) with walls angled outward at seven degrees. Like a slender stalk of bamboo, the record-breaking tower was designed to be both strong and flexible – bendable, but unbreakable.

Taipei 101's strength begins in its roots, 380 concrete piles driven 80 metres through the island's thick clay sediment to reach solid bedrock. The building is widest at its foundation, narrowing at a five-degree angle for 25 floors before arriving at the first of the eight identical sloped sections. The tower's core stability comes from eight forged steel megacolumns, each measuring 3.0m x 2.4m and filled with concrete. The megacolumns are trussed to the building's outward-sloping frame with ductile steel braces that bend in an earthquake.

At 700,000 tons of steel, concrete and glass, Taipei 101 is actually light for its height. To steady the tower in gale-force winds, it's equipped with an internal pendulum called a 'passive tuned mass damper', whose massive weight (660 tons) pulls instinctively in the opposite direction of swaying (see 'The Damper' boxout). The result is not only one of the tallest, but perhaps the most stable building in the world, designed to withstand a 2,500-year seismic shock.



Layers upon layers
The 660-ton ball was assembled on site using 44 layers of steel plate, each 12.5 centimetres (4.9 inches) thick.


© mailer_diablo

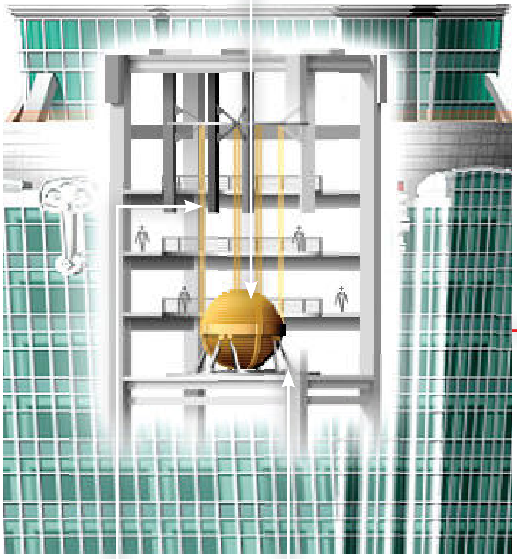
The Damper

A massive pendulum fights the effects of skyscraper seasickness

Suspended from the centre of the 92nd floor of the world's second tallest building is a 660-ton, £543,000 ($800,000) steel ball hanging from four sets of steel cables. The function of the tuned mass damper isn't to keep Taipei 101 upright (its concrete-filled steel backbone is more than sufficient to do this), but to cancel out nausea-inducing swaying in a powerful storm.

If wind pushes the tower to the right, the dangling damper will provide an immediate and equal force to the left, cancelling out the motion. Like a shock absorber in a car, the damper is attached to a series of hydraulic pistons that convert dynamic energy – the swaying of the ball – into heat. Not only is the Taipei 101's damper the largest of its kind, but it's the only one in the world to be incorporated into the aesthetic design of the structure, easily visible from observation decks and restaurants.

Wide load
Taipei's damper is the largest in the world with a diameter of 5.5 metres (18 feet) and weighing as much as 10,000 people.



Cables
The damper hangs from four steel support lines, each consisting of four individual steel cables.

Hydraulics
If the damper swings dramatically during an earthquake, 2m hydraulic pistons absorb and dissipate the energy as heat.

The Statistics

Taipei 101

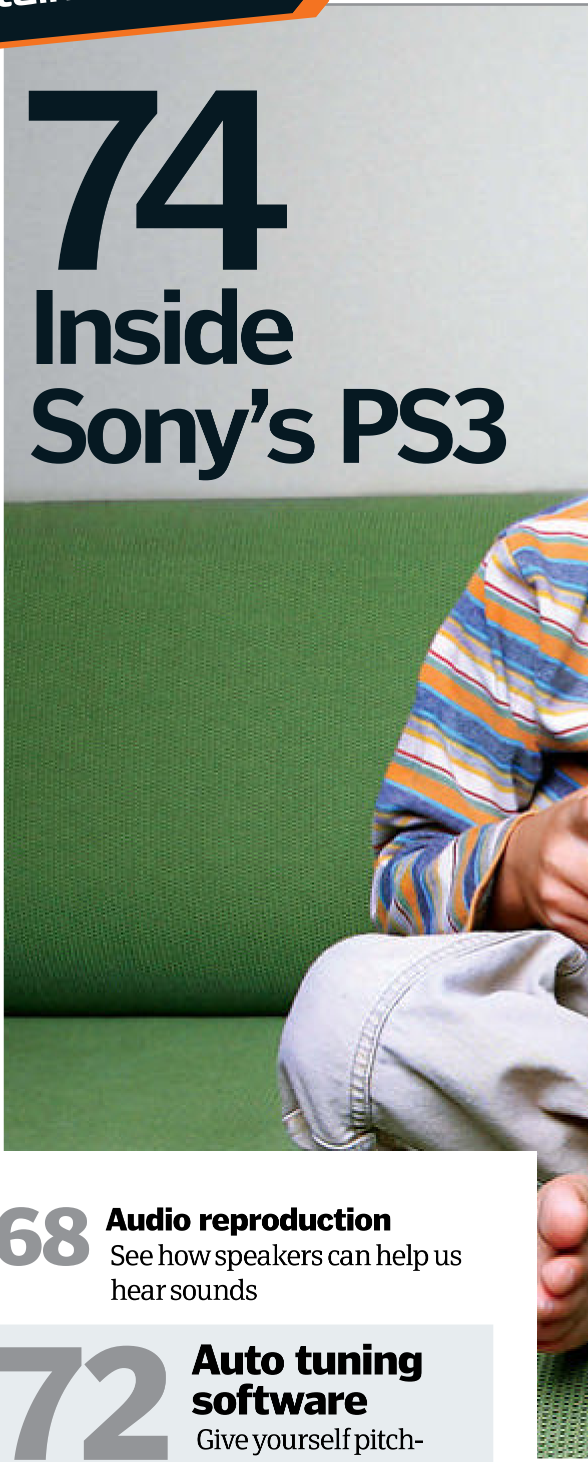
Opened: 2004
Architect: CY Lee & Partners
Height: 508 metres (1,666 feet); 101 storeys above ground
Weight: 700,000 tons
Total floor area: 374,336m²

HOW IT WORKS

ENTERTAINMENT

The recreational devices that keep us entertained

58 A look at Apple TV



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76 View TV over the internet

MOTION CONTROL GAMING

Find out how motion-sensitive controllers have revolutionised the way we play videogames

5 TOP FACTS MOTION-CONTROLLED GAMES

Wii Fit
Format: **Wii**

1 No more cheesy workout DVDs – *Wii Fit* revolutionised exercising at home, hitting the jackpot with its appeal to women and seniors.

Rock Band
Format: **Multiformat**

2 Electronics Arts' answer to *Guitar Hero*, live out your musical stardom fantasies in the privacy of your own living room. Groupies not included.

Heavy Rain
Format: **PlayStation 3**

3 This popular grown-up thriller mystery game now includes Move functionality as well as the usual control-pad interaction.

Sports Champions
Format: **PlayStation 3**

4 Compete solo or against friends in six sports, including archery and volleyball. Can you beat the top scorers in the online leaderboards?

Grease
Format: **Wii**

5 This title uses all of the Wii's functionality to create a great party game – use the Balance Board to dance and the microphone to sing along.

DID YOU KNOW? PlayStation Move sales reached 1.5 million units in one month in Europe alone

At Christmas 2006, the UK went wild for the Nintendo Wii – people queued through the night, stores sold out and now tens of millions of consoles have been sold. Motion-control videogame systems returned to gamers' wish-lists in 2010 as the technology stepped it up a notch. In the September, Sony released the Move controller for PlayStation 3, and in the November, Microsoft launched Kinect, the first controller-free system. And what did we do? Well, we cracked them open to show you what goes on inside of course. Read on to find out just how they work.

Let's start with movement detection. To register its exact position, handheld controllers need a system that can detect motion and speed in three-dimensional space, along with any tilt and twist. The controllers contain tiny accelerometers, micro-electro-mechanical systems (MEMS) which measure acceleration but ignore the effect of gravity. Accelerometers are nothing new – we have biological accelerometers in our ears, the cantilevered beams are tiny hairs (cilia) wafting around in fluid like reeds in water.

MEMS accelerometers consist of tiny strands of silicon attached at one end (cantilevered beams) inside a charged field. The MEMS device measures capacitance (how much charge is stored) so when the beam moves from its neutral position, the change in capacitance can then be used to calculate acceleration.

On Earth, all objects at rest and near the surface are pulled towards the planet with a force of 1G, so manufacturers calibrate their accelerometers to adjust for this. However, it does mean that your Nintendo Wii won't work properly if you were to take it on holiday with you to the moon. Information from the accelerometers is processed in the controller's microchip and beamed back by Bluetooth wirelessly to the sensor.

It's all very well being able to locate the controller in space, but what about movement around the controller's axis? Adding gyroscopic sensors to a controller adds another three dimensions of movement detection. As well as the X, Y and Z planes used to locate the controller, gyroscopes detect movement of the controller around its central axis: pitch (up/down tilt towards the screen) roll (twist) and yaw (aiming the controller to the left or right of the screen). A basic version of this same technology is used in mobile phones to change the image from portrait to landscape depending on which way up the device is held, the iPhone being a perfect example of this technology currently put to extremely good use.

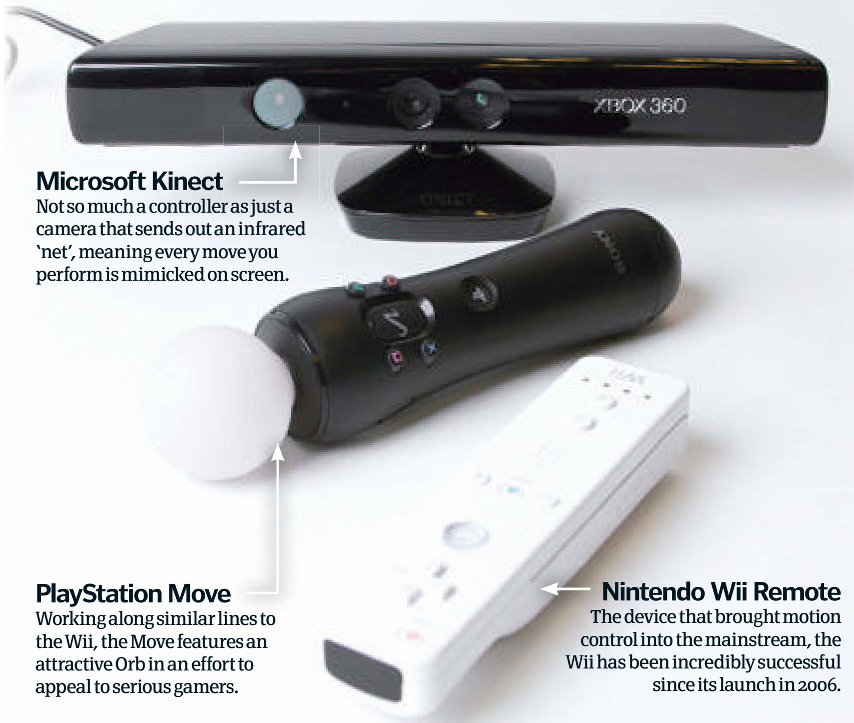
Gyroscopes are an ideal way to detect motion about a central axis – the orientation of a spinning or vibrating gyroscope attached to a low-friction mount remains the same regardless of movement in the surface to which the mount is attached.

There are several different types of MEMS gyroscope sensors – the sensor inside the PlayStation Move, for example, contains a set of three tiny tuning-fork-shaped pieces of quartz placed at mutually perpendicular angles in a charged field. The quartz is piezoelectric so when a current is applied, the forks vibrate. Rotation about the axis of the forks changes the forces at work in the crystal: the plane of vibration remains the same but the frequency of the vibrations changes. Detectors monitor capacitance fluctuations in the charged field to calculate movement of the controller relative to the forks.

▶

The controllers…

Here's a quick overview of each controller



Microsoft Kinect
Not so much a controller as just a camera that sends out an infrared 'net', meaning every move you perform is mimicked on screen.

PlayStation Move
Working along similar lines to the Wii, the Move features an attractive Orb in an effort to appeal to serious gamers.

Nintendo Wii Remote
The device that brought motion control into the mainstream, the Wii has been incredibly successful since its launch in 2006.

Player interaction reaches a new level with motion-controlled gaming

© Microsoft

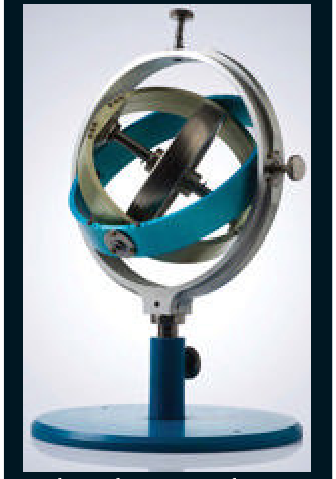
Gyroscope evolution

A new spin on modern gaming

Did you have a spinning top toy? Set it going and it will spin for ages before eventually skidding across the floor. Gyroscopes aren't just a cunning toy for persuading kids that physics is fun; their intriguing properties have many useful motion-detection applications.

The first mechanical gyroscope was built in Germany in the 19th Century and developed by the French physicist Léon Foucault for his investigation of the Earth's rotation. Mechanical gyros like this are used for stabilisation in aeroplanes and boats but they're relatively large and heavy. It wasn't until manufacturers were able to build micro-sized gyros that they appeared in all kinds of electronics devices. Did you ever wonder how a two-legged robot or a Segway scooter stays upright? Both use silicon micro-gyros.

The gyroscope sensor chips are now so small and light that they're widely used in digital cameras for image stabilisation, in mobile phones for screen orientation and in movement-control games where the user twists the handset.



Mechanical gyroscope – the rotating disk spins inside pivoted support rings or gimbals

> *"Infrared LEDs on the Wii are detected in the Wii-mote and triangulated to determine the position on screen"*

1. Move the Wii-mote
Hold the controller as you would a regular table tennis bat – you can even achieve a backhand.

2. Friends not required
Contrary to promotional images of Wii gaming, 2.4 children or a large group of smiley friends aren't necessary. Nice though.

© Nintendo

▶ Motion control systems combine the data from their internal gyroscopes and accelerometers to produce super-accurate information about location in space (X, Y and Z planes), and movement about the controller's axis (pitch, roll and yaw). For extra precision, some systems also throw in a micro-compass (like those used in GPS and satnav systems).

So once the device has accurately detected motion, this needs to be translated to movements that fit on the screen. The Wii system uses infrared tracking to determine the cursor's position on screen. The sensor box above the screen has sets of five infrared (IR) LEDs at both sides. These, plus the IR detector at the top-end of the Wii Remote, mean that the controller's position can be triangulated relative to the screen. So if the LEDs are detected towards the top of the Wii Remote's field of view, the cursor is displayed at the bottom of the screen and vice versa. IR LEDs are used because regular visible light-emitting diodes would be too difficult to pick out from other light sources, especially the screen.

Instead of infrared tracking, the PlayStation Move uses a camera to track visible light from the glowing orb on top of the handheld controller. When it comes to recognising who's actually playing, systems now incorporate a rather ingenious face and voice recognition so players don't have to register or pick an avatar. For face recognition, the PlayStation's EyeCam captures a clear shot of the player's face and then maps individual characteristics onto a face template to store in the system's memory. It detects faces using the same technology used first in Sony cameras for 'smile recognition'.

Motion controllers contain microphones not just for sing-along games but also for voice commands and player recognition – so how does this work? Voice-recognition technology is well-established in communications and accessibility software. The sound waves created by speech become vibrations in the microphone, which are converted to digital signals. The processor removes 'noise' from the data-stream (by subtracting a reading of the background noise in the room) and then breaks down the data into unique speech sounds or 'phonemes' – there are roughly 50 phonemes in the English language. The processor then compares the data to its stored library of phoneme combinations to work out which words were said.

So what about all those notoriously tricky words in English, which are spelled differently but sound the same (homophones)? In order to decide which homophone to register, the processor is also equipped with a context-checker – it analyses the words around the homophone, checks the combination against stored examples and selects the spelling, which is statistically most likely. The software is also advanced enough to recognise many different accents and the latest games systems recognise individual players by storing each user's unique pitch variations, giving you a personal gaming experience every time you turn the console on.

Every different language requires its own library, which can delay the release of products using this technology. Last year the Kinect was initially available in US and UK English, Japanese and Mexican Spanish – while speakers of other languages had to wait until 2011 for updated versions.

With regard to what's next for videogame controllers, developers are hard at work on 3D games (for use with 3D television screens), eye-gaze direction detection and other mind-bogglingly futuristic technology. As handsets begin to become unnecessary and producers create a wider range of games, there will be plenty to satisfy both casual and hardcore gamers.

© Nintendo

Head to Head MOTION CONTROLLERS

THE ORIGINAL

© Nintendo

1. Nintendo Wii
The original mass-market motion-control gaming gizmo. A sell-out at Christmas 2006 and still very popular, especially thanks to its upgrades.

THE COMPETITION

© Sony

2. Sony PS3 Move
Released in September 2010, Sony's controller is lighter, more accurate and prettier, with its colour-changing light orbs.

THE NEXT GENERATION

3. Microsoft Xbox Kinect
No need for batteries, the Kinect does away with a controller. The sensor detects movement, speech and individual players.

DID YOU KNOW? Since its launch in 2006 the Nintendo Wii has sold 75.3 million units worldwide

Nintendo Wii

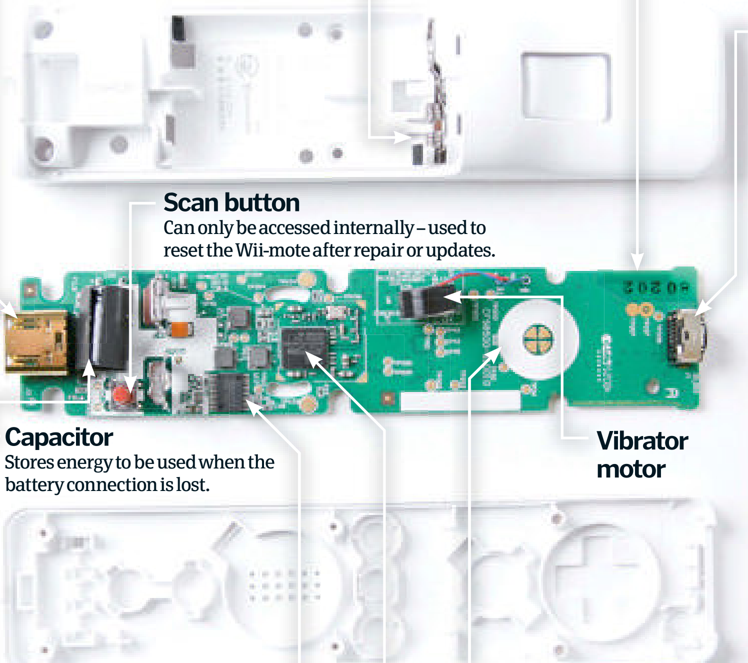
The console that caused a gaming revolution

REAL WORLD

The Wii Remote (Wii-mote) uses a three-axis accelerometer to monitor movement sideways, up and down, forward and back. Two sets of infrared LEDs on the Wii console are detected in the Wii-mote and triangulated to determine the cursor or character position on screen.

Nintendo released the Wii MotionPlus device to enhance the Wii-mote – this adds a three-axis 'tuning fork' gyroscope to better detect twisting and tilting movements of controller itself (pitch, roll and yaw).

Inside a Wii-mote



Nintendo connector
Port for plugging in attachments, such as the nunchuk.

Battery clips

Accelerometers (reverse of board)
Used to locate the controller in 3D space.

IR sensor
Detects IR radiation from the LEDs in the console.

Scan button
Can only be accessed internally – used to reset the Wii-mote after repair or updates.

Capacitor
Stores energy to be used when the battery connection is lost.

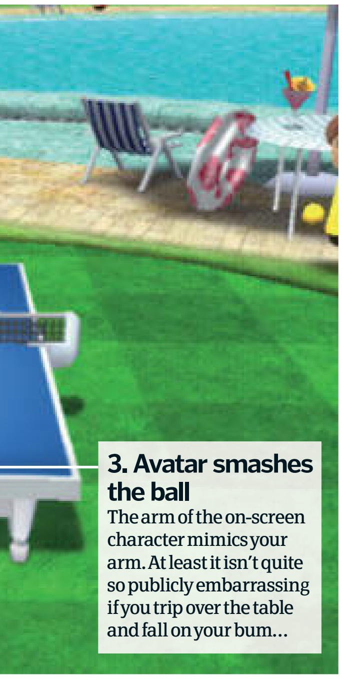
Vibrator motor

Audio processing chip
This is a stow-away! This chip currently isn't used but might be in future as games develop.

Bluetooth chip
Transmits data to the Wii console.

Speaker and 'rumble pack' (reverse of board)
Provide feedback from events on screen, such as hitting a ball.

© Nintendo



3. Avatar smashes the ball
The arm of the on-screen character mimics your arm. At least it isn't quite so publicly embarrassing if you trip over the table and fall on your bum…

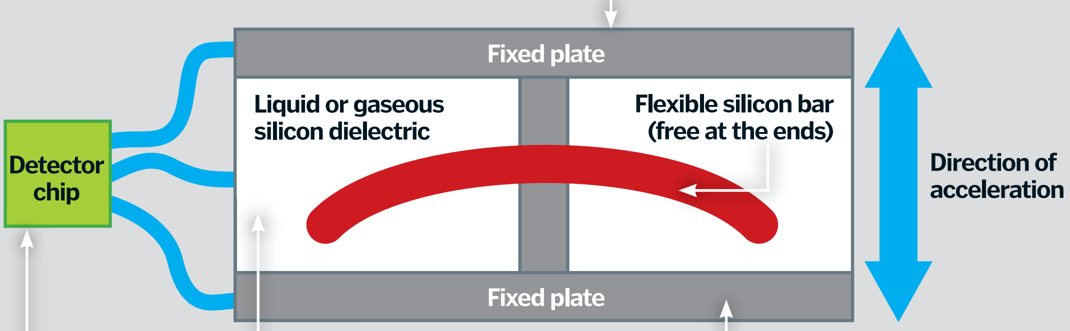
IN GAME

Using the Wii Remote is fairly intuitive. Slip the strap over your wrist and hold it like a remote control, usually with your thumb on the A-button near the top and your index finger on the B-button on the back.

The movements you perform do depend on the game, for example, hold and swing it like a tennis racket, a golf-club or a bowling ball; thrust it like a sword or even steer it like a car. The wealth of options is almost endless.

Inside a capacitive accelerometer

Turning your world around has never been so technical!


Fixed plate
Liquid or gaseous silicon dielectric
Flexible silicon bar (free at the ends)
Detector chip
Direction of acceleration
Fixed plate

Capacitance
Capacitance is a measure of ability to store electric charge. It depends on a system's physical dimensions and its electrical permittivity.

Calculations
The detector registers capacitance fluctuations, converts them into distances and calculates acceleration.

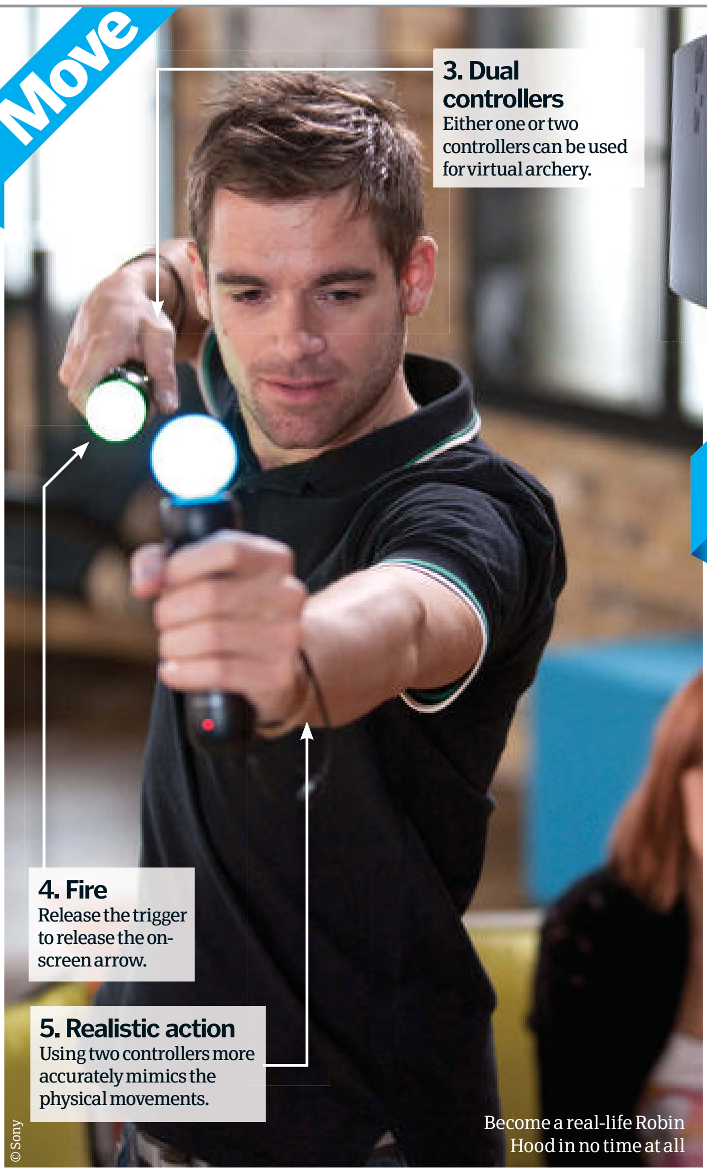
Increased capacitance
If there's less space between a plate and the bar, more charge can be stored so the capacitance is greater.

Accelerometer
In an accelerometer, there are two pairs of plates: the flexible silicon bar functions as a second plate for each of the fixed plates.

> "Move uses a camera to track visible light from the glowing orb"

PlayStation Move

The console king ups its game



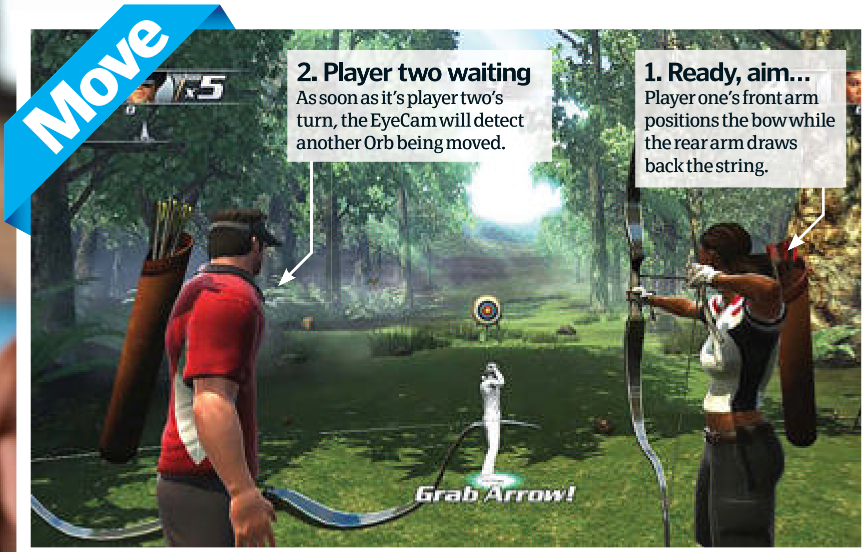
3. Dual controllers
Either one or two controllers can be used for virtual archery.

4. Fire
Release the trigger to release the on-screen arrow.

5. Realistic action
Using two controllers more accurately mimics the physical movements.

© Sony

Become a real-life Robin Hood in no time at all



2. Player two waiting
As soon as it's player two's turn, the EyeCam will detect another Orb being moved.

1. Ready, aim…
Player one's front arm positions the bow while the rear arm draws back the string.

IN GAME

Hold the controller like a microphone with your index finger on the trigger button, and make sure the EyeCam can 'see' the light orb on top.

In the Archery on *Sports Champions*, reach over your shoulder to collect an arrow, bring it over your head and then draw back, releasing the trigger to shoot.

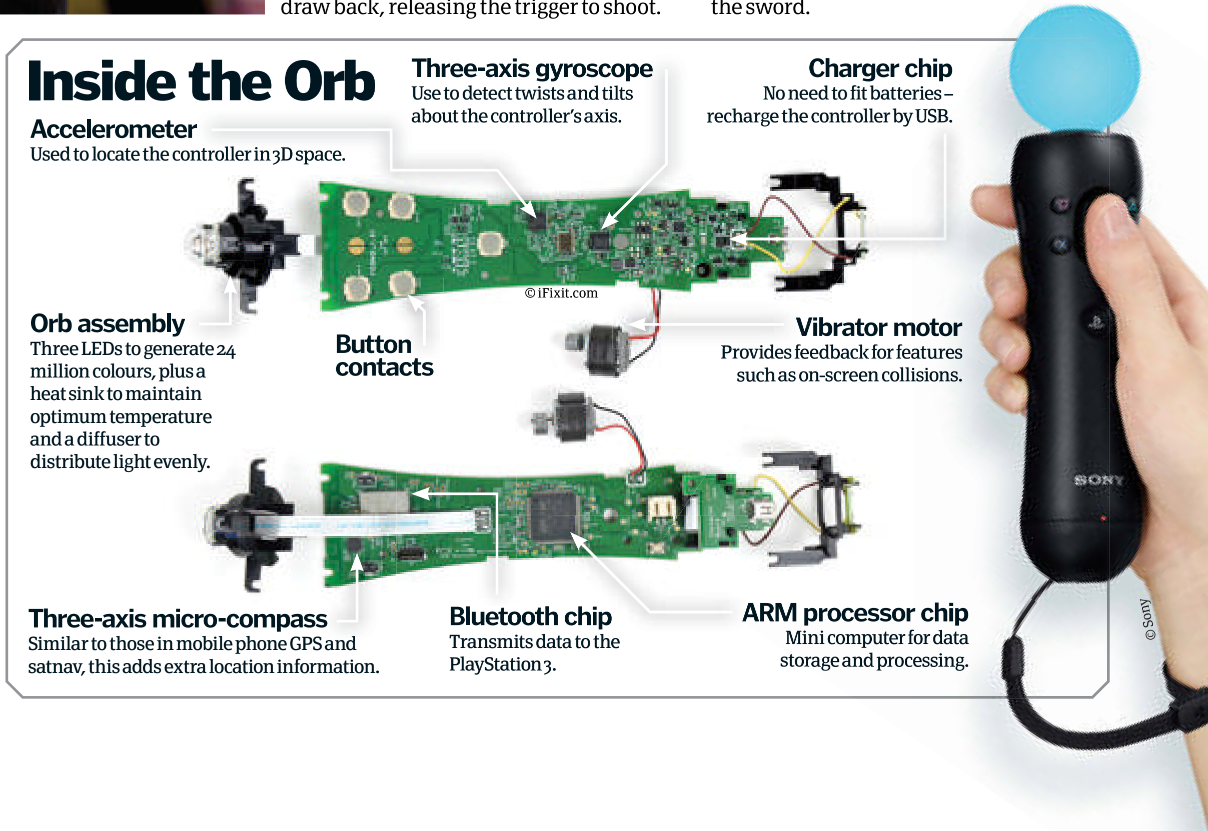
Two controllers can be used to make the movements more realistic. For example, in Archery, the front controller stays still, aiming for the target, while the other draws the bow and releases. In Gladiator Duel, the arm holding the front controller is the shield, while the back controller is the sword.

REAL WORLD

Motion detection takes place both in the EyeCam and in the Move controller itself. The EyeCam tracks the Orb's movement in three dimensions: up/down, left/right (the X and Y planes) and depth (the Z plane). Because the orb is a fixed size, the processor calculates how far away it is using simple laws of perspective: the smaller it appears, the further away it is.

Inside the controller, accelerometers and gyroscopes collect further information about motion including tilt and twist, transmitting this data via Bluetooth to the PS3. The orb contains three LEDs to produce different colours. If you're playing solo, the Move selects the optimum colour to contrast with your surroundings. In multiplayer games, different colours differentiate the players and colours also provide visual feedback on hits and misses.

Inside the Orb



Accelerometer
Used to locate the controller in 3D space.

Three-axis gyroscope
Use to detect twists and tilts about the controller's axis.

Charger chip
No need to fit batteries – recharge the controller by USB.

Orb assembly
Three LEDs to generate 24 million colours, plus a heat sink to maintain optimum temperature and a diffuser to distribute light evenly.

Button contacts

© iFixit.com

Vibrator motor
Provides feedback for features such as on-screen collisions.

Three-axis micro-compass
Similar to those in mobile phone GPS and satnav, this adds extra location information.

Bluetooth chip
Transmits data to the PlayStation 3.

ARM processor chip
Mini computer for data storage and processing.

© Sony

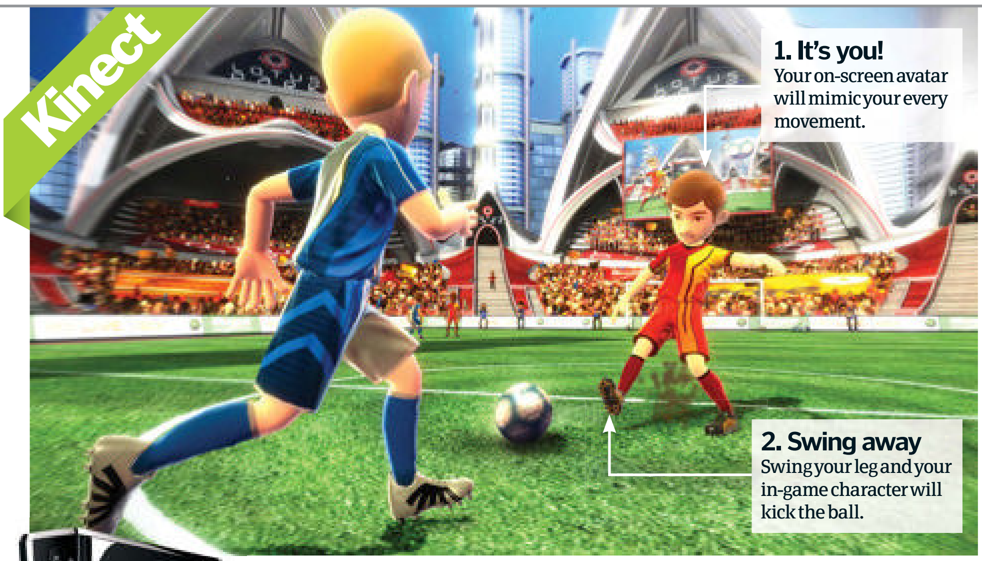
DID YOU KNOW?

© Microsoft

You've been framed!

Kinect's body-tracking web-style camera technology is capable of not only zooming in and following the player around the room, it can also detect a second person and will then pan out to watch both people at once. And if another person enters the room the camera will reframe the picture to fit everyone in.

DID YOU KNOW? *Kinect broke the Guinness World Record for fastest-selling consumer electronics device*



1. It's you!
Your on-screen avatar will mimic your every movement.

2. Swing away
Swing your leg and your in-game character will kick the ball.

Microsoft Kinect

Forget controllers; the future's hands-free

IN GAME

With no controller to hold, Kinect is simple. Once you've enrolled, just move your body, gesture or speak. Scroll through virtual libraries by waving your hand or speak the name of a video you want to watch. In multiplayer quizzes, clap to 'buzz in' and answer by speaking. The Kinect can track up to six players, with a maximum of two actively moving to control a game.

REAL WORLD

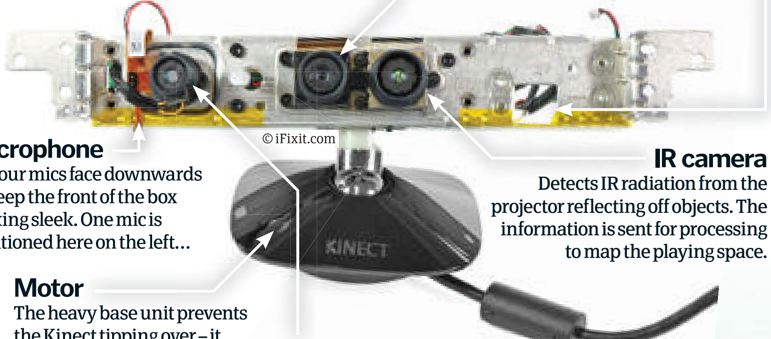
With Kinect switched on, you only need to appear in its field of view to 'sign in'. On first use, the sensor must be calibrated – it scans the room, tilting to 'see' the floor plane and enrols players by storing their body dimensions and facial details. Whereas Move tracks the light-orbs, Kinect assigns 20 tracking points on your body. Thinking of crash-dieting or radical surgery? You'll need to re-enrol.

Kinect's RGB camera monitors players' movements while a processor compares them to its library of hundreds of moves. To detect depth, the system constantly projects infrared radiation, which reflects off objects in the room. The infrared camera in Kinect detects the reflections to create a 'view' of the playing space with objects that are nearer the sensor appearing a brighter colour. It's not like IR thermal imaging used in night-sight gadgets that detect body heat – it's more similar to the technology is used in landscape mapping.

Inside Kinect

RGB camera
This ordinary digital camera detects visible light and sends images for identification and processing.

Microphones
…the other three mics are on the right. Kinect developers tested dozens of arrays to arrive at this optimum configuration.



© iFixit.com

Microphone
All four mics face downwards to keep the front of the box looking sleek. One mic is positioned here on the left…

IR camera
Detects IR radiation from the projector reflecting off objects. The information is sent for processing to map the playing space.

Motor
The heavy base unit prevents the Kinect tipping over – it contains the motor, which tilts the sensor and operates the camera's zoom.

IR projector
Constantly beams IR radiation into the playing space.

© Microsoft

3. Get involved
You're the controller when it comes to Kinect, what could be more natural?

4. Detection
Every move you perform will be picked up by the camera.

History of motion control

Anyone remember *Duck Hunt*, with the annoying dog who chuckled when you missed the ducks? If you played with light guns and used a joystick back in the Eighties, you were using the very first motion-control gaming systems.

Nintendo achieved spectacular flops in the early-Nineties with the Power Glove and the Virtual Boy 3D system (not gender-biased, it was named like the Game Boy), which was worn on the gamer's head. Not a good look, it didn't catch on.

Sony's Move technology is the modern evolution of the company's EyeToy gizmo – essentially a camera that detected faces and grafted them onto characters in games. Cute but gimmicky.

Flight simulators are a successful example of motion-control technology and are used in both education and games.

Who says it doesn't make you look cool?

> "The built-in Wi-Fi chip utilises your broadband connection to push the rented video to the Apple TV box"

Apple TV explained

Its main purpose is to stream movies and shows to a TV, but how does Apple work?

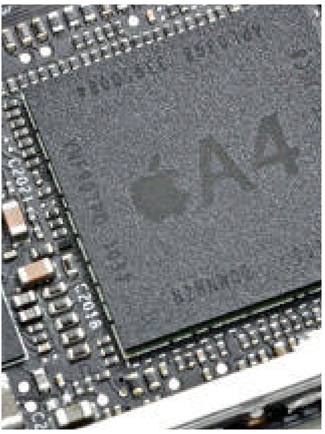
Apple TV is designed to work with many Apple products and services, including iPhones, iPads, iTunes, a desktop PC and of course a TV. The built-in software, a stripped-down version of Mac OS X, offers access to movies and shows that you can rent any time, and the built-in Wi-Fi chip utilises your broadband connection to push the rented video to the Apple TV box.

It also connects with your desktop-based iTunes library to create a single hub with which to view your media in the comfort of your favourite chair. Despite not physically storing video, the 8GB flash chip is used to cache films as they are playing to ensure that they do not skip and in most cases the full film will be downloaded to the Apple TV flash memory even if you haven't finished watching it.

The controller software is the hub around which everything works. Once connected to a TV and a computer running iTunes, it will detect when changes are made, such as renting a video, and it will then send the relevant information to each part of your network. For example, it will allow your desktop to send the film to the TV box and onwards to the TV itself.

Apple TV is designed to do one thing above all else: stream video and photos. Because of this it is capable of assigning all of its resources to this one task and does not have to deal with multiple instructions at the same time. The A4 processor has to deal with multiple functions and provided the incoming broadband connection is stable and fast, the whole experience will be faster than competing streaming products. The built-in 8GB of flash memory ensures that the streamed video is cached while it is playing, which in effect stores the film ahead of its playing time to eliminate any stoppages.

The low price point has been reached by using parts that are either mass produced by other companies or already in volume production by Apple, ie the A4 processor, which is used in the iPad and new iPod touch devices. The technology behind Apple TV is surprisingly simple, but of high enough quality to pull off the task at hand at lightning speed.



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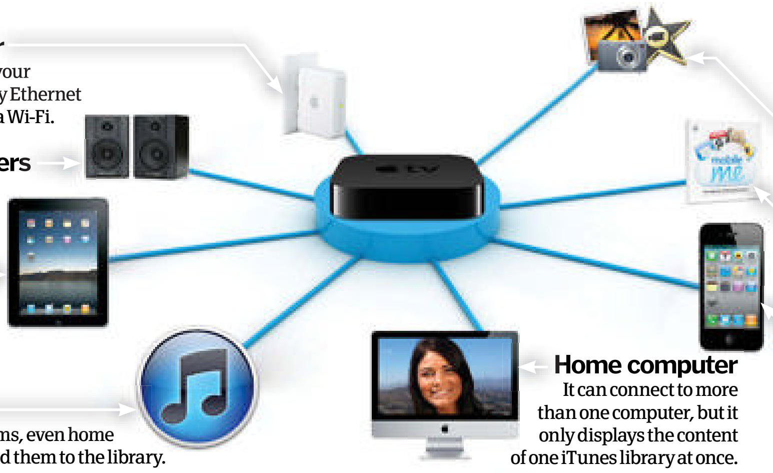
What can it connect to?



Wireless router
Connect Apple TV to your network physically by Ethernet cable or wirelessly via Wi-Fi.

External speakers
Apple TV can be connected to external speakers.

iPad
You can share movies and photos and display them on the big screen.

iTunes
Stream music, TV, films, even home movies if you've added them to the library.

Home computer
It can connect to more than one computer, but it only displays the content of one iTunes library at once.

iPhoto and iMovie
Share your library of slideshows, photos and home-made videos.

MobileMe
In addition to the iTunes Store, you can also access YouTube, Flickr and MobileMe.

iPhone
Version 4.2 of iOS enables AirPlay, which means you can wirelessly transmit a movie, TV or photo file from your iPhone, iPod touch and iPad to your Apple TV.

THE STATS APPLE TV 2

WEIGHT 0.27kg WIDTH 9.91cm POWER 6 watts

VIDEO FORMATS 3 AUDIO FORMATS 9 SPEED 30fps

DID YOU KNOW? *You can control Apple TV 2 from an iPhone, iPod touch or iPad using the free Remote app*

Inside the Apple TV 2

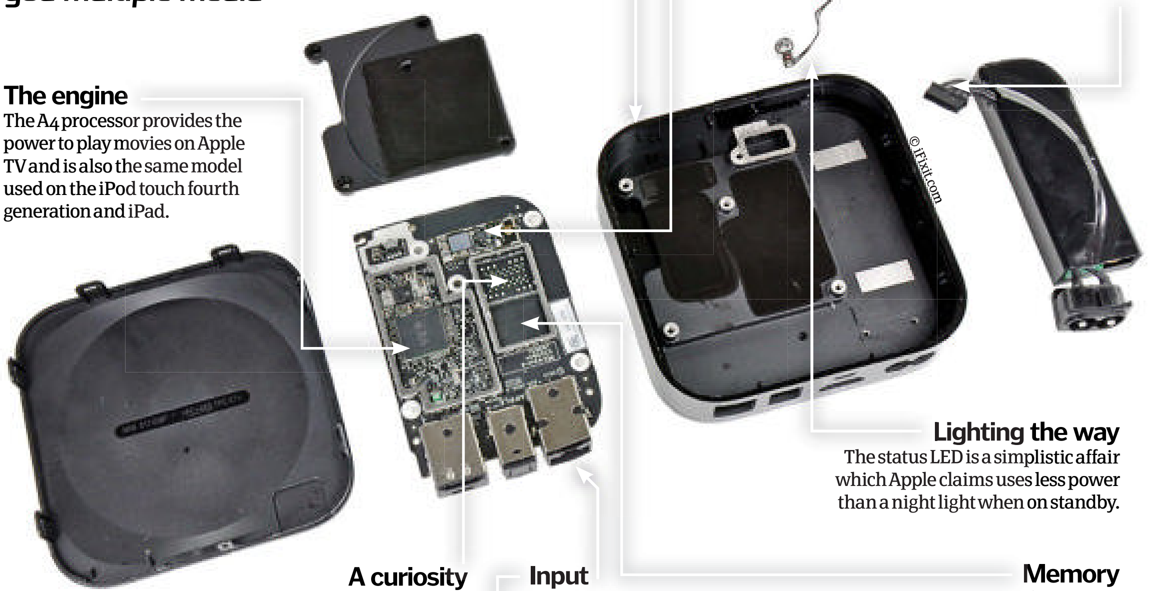
Under the hood of the black box of tricks that brings you multiple media

Housing
The housing is quite bland from the inside, but displays all of the traits that signify the allure of Apple products on the exterior.

Communication
The Wi-Fi board is made by Panasonic and on it is housed a Broadcom chip for Wi-Fi, Bluetooth and FM communication. The same chip is used on the Apple iPad.

Power
The power supply is of course an important component and in this case it is merely a selection of cables connected to the logic board with an output of only 5.95 watts.

The engine
The A4 processor provides the power to play movies on Apple TV and is also the same model used on the iPod touch fourth generation and iPad.



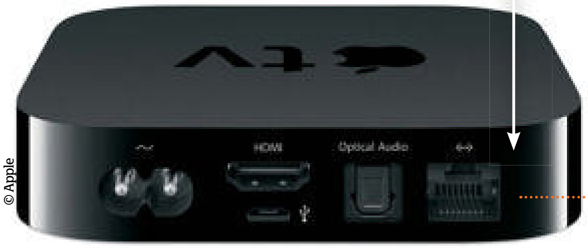
© iFixit.com

Lighting the way
The status LED is a simplistic affair which Apple claims uses less power than a night light when on standby.

A curiosity
There is an empty space next to the Samsung flash chip which is identical in size, suggesting that another flash chip could be added by the serious tinkerer.

Input
The HDMI, audio out, Ethernet, Micro-USB and AC adaptor ports are quite large internally, but retain an unobtrusive look from outside.

Memory
One surprising inclusion is an 8GB flash chip from Samsung which is used for caching your movies while they are streaming.



© Apple

Remote
You need the Apple TV remote to set it all up; your iPhone Remote app won't work till Home Sharing is enabled.

© iFixit.com

The statistics...

Apple TV 2

Manufacturer: Apple

Dimensions: 9.9 x 9.9 x 2.3cm (3.9 x 3.9 x 0.9in)

Weight: 0.27kg

Unit price: £99

Operating system: Alternate Mac OS X 10.4.7

Processor: Apple A4

Connectivity: Wi-Fi 802.11 a/b/g

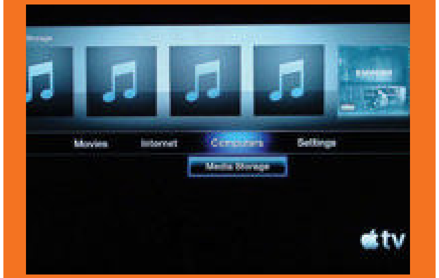
Launch date: 1 September 2010

Learn more

For more info and images of the exposed Apple TV 2, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.

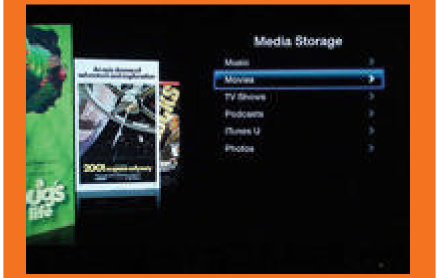
How to use Apple TV

The software built in to Apple TV 2 is designed to work on your TV and you can browse the latest movies and TV shows just as you would on iTunes. Click the 'Rent' button and your movie will be streamed to the box and start playing immediately. The system includes menu options to access YouTube and NetFlix as well which work just as they do on an iPad or desktop. On top of this you have access to your home movies and photos stored in your iTunes library so all of your media is just a click away. Throw HD podcasts, web browsing and internet radio into the mix and you can start to see how quickly Apple TV could become a big part of your life.



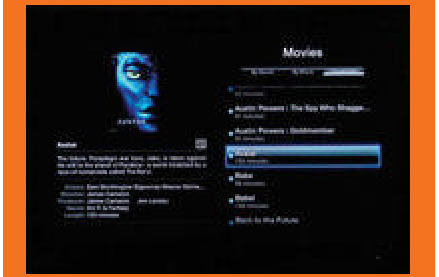
Step 1 – Search the library

In the Computers menu choose from the list of iTunes libraries. You may only search through one library at a time.



Step 2 – Select a menu

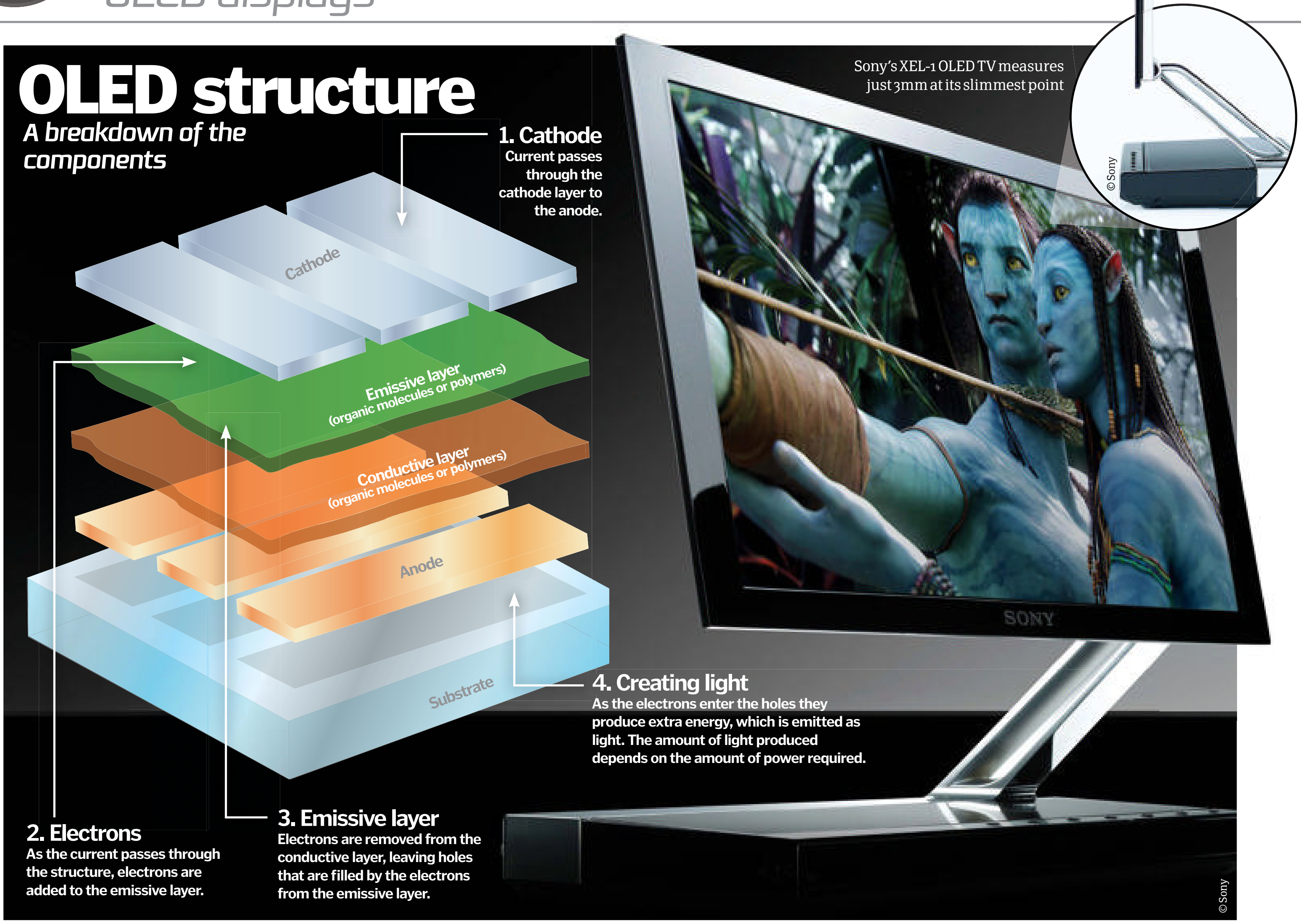
Select from six menus. Choosing the Genre option organises your movies into handy categories to scroll through.



Step 3 – Choose a movie

Select the movie of your choice and it'll play. As with a DVD you can use the fast-forward, rewind and pause options.

> “The key benefits to OLED displays stem from the lack of a backlight”



OLED structure

A breakdown of the components

1. Cathode
Current passes through the cathode layer to the anode.

2. Electrons
As the current passes through the structure, electrons are added to the emissive layer.

3. Emissive layer
Electrons are removed from the conductive layer, leaving holes that are filled by the electrons from the emissive layer.

4. Creating light
As the electrons enter the holes they produce extra energy, which is emitted as light. The amount of light produced depends on the amount of power required.

Cathode
Emissive layer (organic molecules or polymers)
Conductive layer (organic molecules or polymers)
Anode
Substrate
SONY

Sony’s XEL-1 OLED TV measures just 3mm at its slimmest point

© Sony

© Sony

How OLEDs work

Measuring just 3mm thick, OLED displays are changing the face of our TVs and mobile phones

TVs have come a long way since the massive boxes hogging the corner of your living room. Yet even your current flat-screen LCD TV will soon look unwieldy compared to the next generation of products. With OLED (organic light-emitting diode) technology TVs, computer monitors, mobile phones and pretty much anything else with a screen are set to become thinner than ever before.

OLED is a major step on from the LCD technology that is currently used. In simple terms, it is created from organic materials that emit light when power is passed through it. An OLED display contains thin films of organic materials placed between two conductors; as the current passes through, the display lights up. This self-illuminating function removes the need for the backlight that is an essential requirement of a traditional LCD screen.

There are two kinds of OLED display, of which AMOLED (active matrix) is the most important. Designed for larger displays (over 7cm/3in), it allows for each individual pixel on the screen to be controlled separately.

The three key benefits to OLED displays all stem from that lack of a backlight. The immediate consequence is that devices can be made thinner – a 100cm (40in) LCD TV needs a backlight large enough to span and light the entire surface of the screen evenly. Without this problem, the same sized OLED-based TV could be little more than a few centimetres thick, and as miniaturisation of the other components powering devices develops further, they will only continue to get thinner.

The next benefit is that without that backlight, the screens draw far less power. While a black image on an LCD display is backlit to the same degree as a white screen, the light on an AMOLED display directly corresponds to the brightness of each individual pixel. For devices that run on battery power, like mobile phones, this is a massive boon. The final benefit comes in the form of a massive improvement in image quality, with greater contrast between light and dark colours thanks to the absence of the backlight that turns blacks into dark greys on a traditional LCD.

Of course, thinner hardware is only the first step in what OLED technology will bring us. Through nanotechnology companies like Sony and Toshiba have created screens that measure less than half a millimetre thick, making them extremely flexible. Imagine a mobile phone with a large screen that can be folded to keep it pocketable, or even wearable computers built into clothing – this is no longer just the stuff of science fiction.

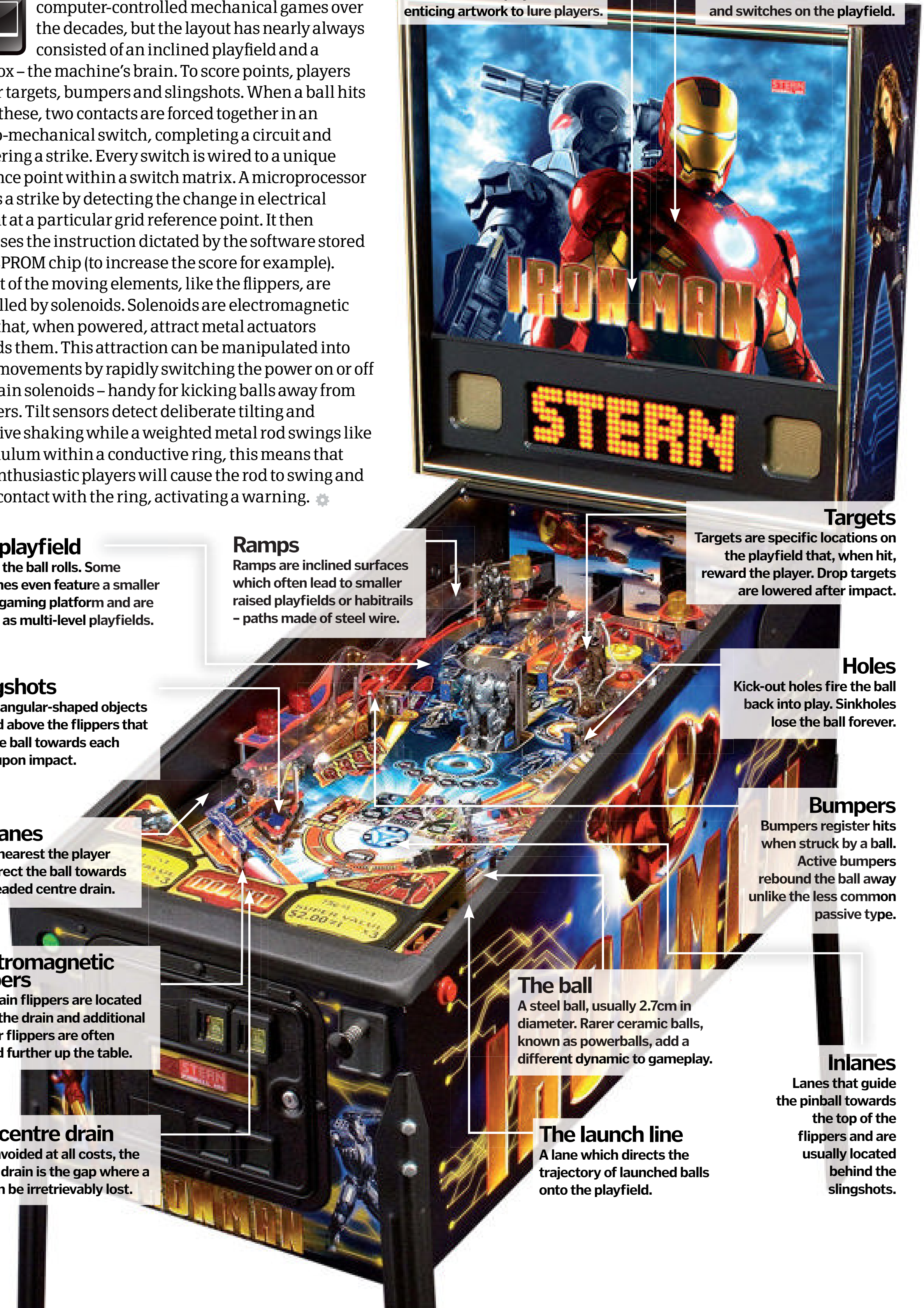
DID YOU KNOW? *A typical modern pinball machine consists of over 3,500 components including over half a mile of wiring*

Pinball machines

What lies beneath these mechanical marvels?

Pinball machines have evolved into complex, computer-controlled mechanical games over the decades, but the layout has nearly always consisted of an inclined playfield and a backbox – the machine's brain. To score points, players aim for targets, bumpers and slingshots. When a ball hits one of these, two contacts are forced together in an electro-mechanical switch, completing a circuit and registering a strike. Every switch is wired to a unique reference point within a switch matrix. A microprocessor locates a strike by detecting the change in electrical current at a particular grid reference point. It then processes the instruction dictated by the software stored in an EPROM chip (to increase the score for example).

Most of the moving elements, like the flippers, are controlled by solenoids. Solenoids are electromagnetic tubes that, when powered, attract metal actuators towards them. This attraction can be manipulated into quick movements by rapidly switching the power on or off to certain solenoids – handy for kicking balls away from bumpers. Tilt sensors detect deliberate tilting and excessive shaking while a weighted metal rod swings like a pendulum within a conductive ring, this means that over-enthusiastic players will cause the rod to swing and make contact with the ring, activating a warning.



The backbox
The upright unit that contains the master circuit boards, dot matrix score display and enticing artwork to lure players.

Wiring
One set of wiring provides power to the lamps and the other controls the solenoids and switches on the playfield.

The playfield
Where the ball rolls. Some machines even feature a smaller raised gaming platform and are known as multi-level playfields.

Ramps
Ramps are inclined surfaces which often lead to smaller raised playfields or habitrails – paths made of steel wire.

Targets
Targets are specific locations on the playfield that, when hit, reward the player. Drop targets are lowered after impact.

Slingshots
Two triangular-shaped objects located above the flippers that kick the ball towards each other upon impact.

Holes
Kick-out holes fire the ball back into play. Sinkholes lose the ball forever.

Outlanes
Lanes nearest the player that direct the ball towards the dreaded centre drain.

Bumpers
Bumpers register hits when struck by a ball. Active bumpers rebound the ball away unlike the less common passive type.

Electromagnetic flippers
Two main flippers are located above the drain and additional shorter flippers are often located further up the table.

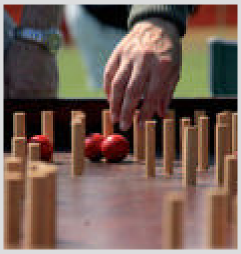
The ball
A steel ball, usually 2.7cm in diameter. Rarer ceramic balls, known as powerballs, add a different dynamic to gameplay.

Inlanes
Lanes that guide the pinball towards the top of the flippers and are usually located behind the slingshots.

The centre drain
To be avoided at all costs, the centre drain is the gap where a ball can be irretrievably lost.

The launch line
A lane which directs the trajectory of launched balls onto the playfield.

A HISTORY OF PINBALL



1700s In the game of bagatelle, players use cue sticks to hit balls up an inclined playfield which rebound off pins into scoring holes.

1871 Patent awarded for Montague Redgrave's "ball shooter" – a coiled spring ball launcher, similar to today's plungers.

1931 Coin-operated pingame machines like Whiffle, and Baffle Ball surge in popularity. Pingames start to be referred as pinball machines.

1933 Pinball machines go electric. Pacific Amusements Company's 'Contact' machine features electric bells and solenoids, adding momentum to the ball.

1939 American cities begin to outlaw pinball machines. As 'games of chance' they are classified as illegal gambling devices.

1947 Gottlieb's Humpty Dumpty machine features the first electromechanical flippers, billed as "the greatest triumph in pingame history".

1976 New York ban overturned. Editor Roger Sharpe proves pinball requires skill by correctly predicting a shot in front of journalists.

1977 Solid state microprocessors are introduced, bringing new game innovations, reliability and design elements.

1991 The *Adams Family* machine is released and becomes the most successful pinball game of all time.

1999 *Pinball 2000* is launched, featuring interactive 3D holographic videogame characters. It achieves limited success but is discontinued.

2010 Just a handful of pinball manufacturers remain, the largest being Stern Pinball, Inc. It produces three to four titles a year.

Image © Stern Pinball Inc.

Leave the paper and pencil behind

© Nintendo

LAP 3/3
6th
TIME 1:00:37
1
2
3
4
5
6
7
8
X
A
Y
B
START
SELECT
POWER

© Nintendo

How does a Nintendo DS work?

It's big, it's bold, it's brash, but is it beautiful inside and out?

The 'XL' in Nintendo DSi XL symbolises its ability for more than one player to enjoy the device at a time thanks to the large screens that display at a low resolution to increase the size of each pixel. It may not be pin sharp, but it is much clearer from a distance. Married to TFT screen technology that carefully aligns each pixel for much wider viewing angles, the experience is more engrossing than ever before. The 'i' in DSi symbolises the two cameras that have been designed with one facing towards and the other away from the user; they are low resolution at only 0.3 megapixels, but are complemented by software that lets you distort photos, add special effects and share wirelessly on social networks. The DSi XL is standalone thanks to the inclusion of 802.11b/g Wi-Fi, which gives the device speedy wireless internet access up to 36 metres from a wireless router or hot spot and also allows access to the Nintendo Wi-Fi Connection Service, designed to allow free online play against other Nintendo users.

The included 16MB of RAM is primarily used by the DSi Browser for speedier surfing and to store cached pages and images while the 256MB of flash memory is used to store downloaded games and other media. The 133MHz processor is twice as fast as previous models and processes gameplay mechanisms alongside another, slightly slower, processor which processes sound, Wi-Fi and other background functions. The two work in tandem to spread the load of multiple actions at any one time. Good sound is achieved through large speaker enclosures. The large battery can last for up to 17 hours on a low brightness setting.

Finally, the audio recorder uses audio filters for excellent recorded sound by eliminating some sound types and letting others through. This is just one lesser-known example of the huge amount of technology that has been squeezed into the DSi XL.

Most of the technological improvements to be found in the DSi XL model are not simply the result of improved innovation, but also the ability to use larger components in a larger housing. ✲

The statistics...

© Nintendo

DSi XL

Manufacturer: Nintendo

Dimensions: 91 x 161 x 21mm (3.6 x 6.3 x 0.8in)

Weight: 314 grams

Unit price: £144.99

CPU: 133MHz

Storage: 256MB

Connectivity: Wi-Fi 802.11b/g

Launch date: 29 October 2009

Total sales: Over 4 million

The history of portable gaming

Handheld gaming has endured a rocky history. Here we take a look at the devices that stood out and those that fell by the wayside...

1989

The Atari Lynx was the world's first colour portable gaming system, but its reign was soon eclipsed by the legendary Nintendo Game Boy, which dominated for years to come.

1991

1991 was all about the Sega Game Gear, which managed to become the trendy must-have item long before portable technology became fashionable.

1998

The Game Boy Color took many years to reach the masses, but sold by the bucketload. Even the hard-to-see screen did not deter the gaming community.

2003

Nokia wanted a piece of the action and launched N-Gage which was an abject commercial and consumer failure. It never did recover enough ground to remain viable.

Head to Head
HANDHELD DEVICES

CHEAP

1. Nintendo DSi
The DSi is one of the cheapest handheld gaming systems available and boasts hundreds of games, some of which are also priced keenly.

MID-RANGE

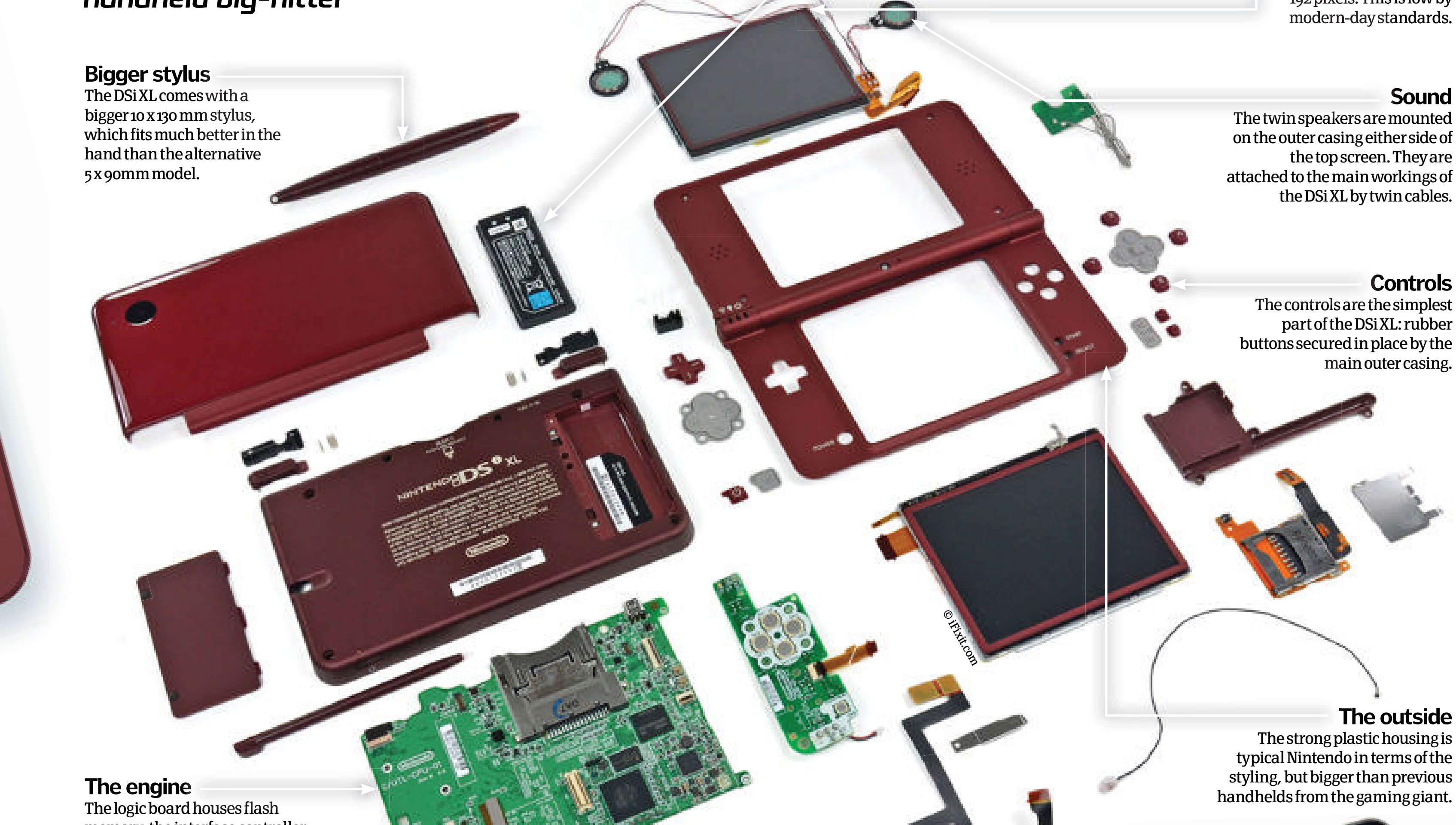
2. Sony PSP Go
Sony has pushed the price of the PSP Go to the lower limit, but has still managed to produce a well-built console for the serious gamers out there.

EXPENSIVE

3. iPhone 4
The iPhone 4 is by far the most expensive – once you include the contract – but it can play games and do almost anything else you need it to do.

DID YOU KNOW? *The DSi XL comes with two styluses: the small one fits inside the device and the larger one is carried separately*

Inside the DS
Taking apart Nintendo's handheld big-hitter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Power
The 1050 mAh battery offers 25 per cent more power than the battery in the standard DSi and is required to cope with the larger screens.

Screens
Each of the two screens measure 107mm (4.2 in) diagonally but have resolutions of only 256 x 192 pixels. This is low by modern-day standards.

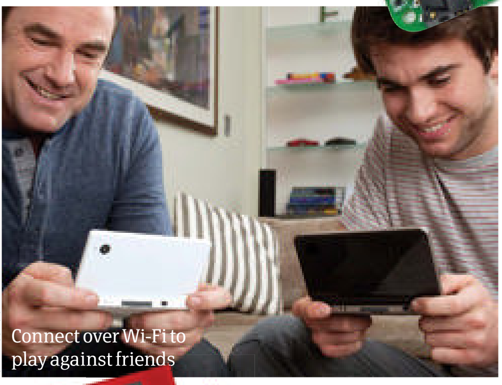
Bigger stylus
The DSi XL comes with a bigger 10 x 130 mm stylus, which fits much better in the hand than the alternative 5 x 90mm model.

Sound
The twin speakers are mounted on the outer casing either side of the top screen. They are attached to the main workings of the DSi XL by twin cables.

Controls
The controls are the simplest part of the DSi XL: rubber buttons secured in place by the main outer casing.

The outside
The strong plastic housing is typical Nintendo in terms of the styling, but bigger than previous handhelds from the gaming giant.

The engine
The logic board houses flash memory, the interface controller, ARM CPU and almost everything else that makes the DSi XL work.


© Nintendo

Connect over Wi-Fi to play against friends

Connectivity
The Wi-Fi board is similar in size to a memory stick, but is capable of keeping the DSi XL connected at long range. It is attached directly to the main logic board.

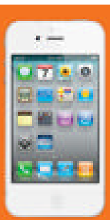
Learn more
For more info and images of the exposed DSi XL, visit the gadget surgeons at ifixit.com who kindly contributed photos and findings for this article.

ifixit

2004
The Nintendo DS demonstrated the company's ambitions in the portable gaming market and was an instant smash.

2005
The Sony PSP proved that powerful console gaming was possible in a handheld device and received praise from critics.

2007
The iPhone was never purely a games console, but quickly became a foe to Nintendo and Sony, and has hurt sales from both companies.



2009
The PSP Go is Sony's attempt to shore up the flagging PSP range. It's had limited success to date.

© Nintendo

The extra screen real estate is a definite plus

How slot machines work

Beating the one-armed bandit is even harder than you think

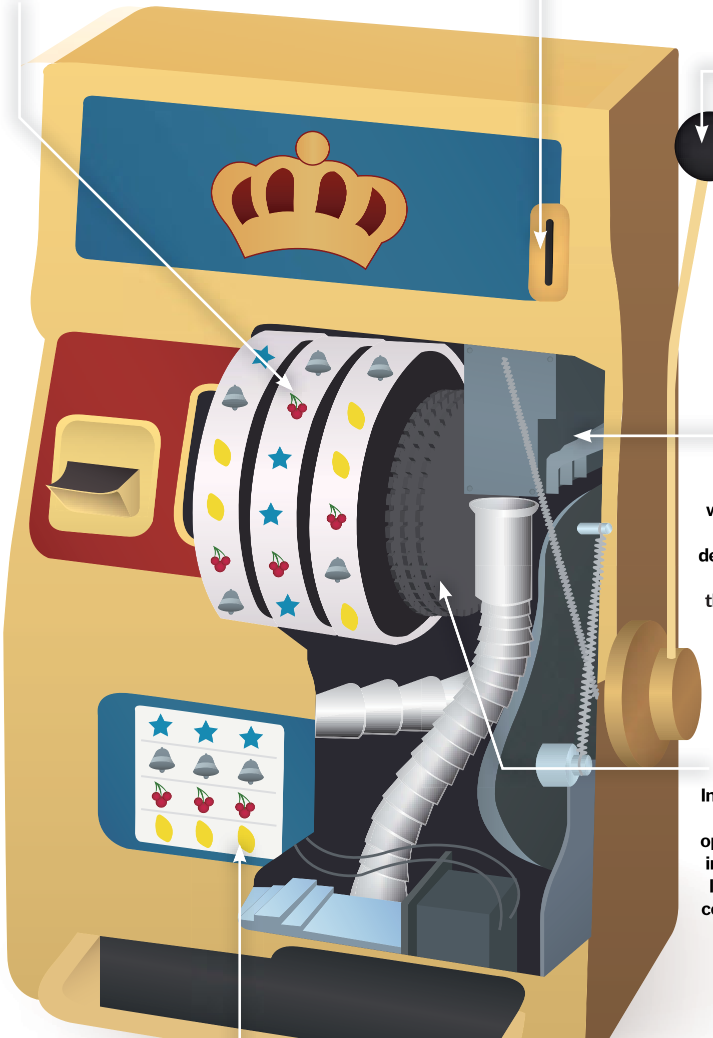
Images © Bally

Most amateur gamblers believe that if a slot machine hits the jackpot, then it immediately goes 'cold'. They also believe the opposite is true: if a machine runs cold for hours, then it's 'due' for a big payoff. But if you look inside modern slot machines, you learn the cold hard truth. Every single pull of the lever has equal odds of winning, and those odds are steep.

Since the earliest mechanical slot machines, gaming manufacturers have weighted the machines to tweak the odds. If you look closely at the reels of old machines, you'll find many more blanks and low-scoring symbols than pots of gold, especially on the third or final reel. This creates the famous 'near miss' effect.

Modern slots have replaced the gears, cranks and stoppers with precision step motors and random number generators (RNG). When you pull the crank on a modern slot, a built-in RNG selects three numbers between one and 64. Each number corresponds to one of 22 spots on the three reels. The trick is that half of the numbers between one and 64 correspond to blank spots and only one random number matches the jackpot symbol. The odds of nailing the jackpot are 1/64 x 1/64 x 1/64 or one in 262,144.

The lever is just for show. Three internal step motors spin each reel and stop them precisely at the positions chosen by the RNG. Still feeling lucky?



3. Reels
Three notched reels spin independently around a horizontal metal shaft. On old-fashioned machines, small pegs click into place to stop the spin on a 'random' symbol.

1. Coin slot
Modern slot machines not only take multiple coins, but accept paper money, credit cards and casino 'player' cards.

2. Lever
On mechanical slot machines, pulling the lever was necessary to trigger the spinning of the reels. Motors replaced that function decades ago, leaving the levers for show.

5. Payout trigger
These metal pins work in tandem with the reel plate to determine the payout amount. The better the combination, the longer the trigger is released. A jackpot dumps it all.

4. Reel plate
In the old mechanical slots, the reels operate like tumblers inside a combination lock. When the right combination hits, the tumblers align, triggering a set payout.

6. Winning line
Slot machines offer different payouts for different symbol combos. On modern slots, your payout increases with larger bets. The jackpot is usually reserved for the maximum bet.

Return vs payback

There is no such thing as a 'loose' or 'tight' slot machine. In modern casinos, slot machines are programmed to deliver a precise return percentage, somewhere around 95 per cent. That means 95 per cent of the money that goes into a slot machine is paid back out to the players – the casino keeps the rest.

But here's where things get tricky. The return percentage is not the same as the payback, which is the actual amount of money you win or lose during each gambling session at a slot machine. If you sat down at a slot machine for eternity and pulled the lever an infinite number of times, your payback percentage would be exactly 95 per cent. Likewise, in a casino full of gamblers, the collective machines will pay back roughly 95 per cent of the total money gambled during the course of a day.

Unfortunately, you are only one person and you don't have infinite pulls. So your odds of winning are equally good or bad every pull. You could lose all day and that doesn't mean the machine is rigged. And it doesn't mean that the guy who wins the jackpot found the 'loose' machine. He just got very, very lucky.

Head to Head ELECTRIC GUITARS

BIG

1. Six-string electric guitar
Whether a Fender Stratocaster or Les Paul, this instrument provides a sound big and versatile enough for pop or rock.

BIGGER

2. Doubleneck electric guitar
This extravagant twin-necked variant provides a normal six-string electric and the more twangy 12-string equivalent.

BIGGEST

3. Electric bass guitar
Biggest in build of the electric guitar instruments, it has a longer neck and thick strings to achieve that deep bassy thump.

3x images © Fender muscial instruments corp

DID YOU KNOW? Many famous players 'coil tap' or rewired their pickups 'out of phase' to achieve signature tones

Electric guitars

The science behind what enables an electric guitar to produce that iconic loud sound

Slash doing his fretwork homework

© daigooliva

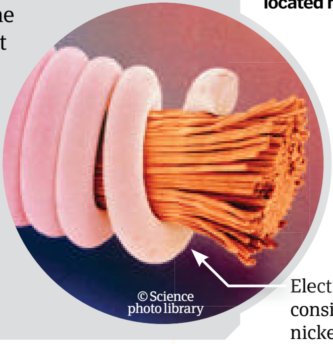
As opposed to an acoustic equivalent, which uses a hollow body to amplify the vibrating strings, a solid-body electric guitar requires a set of pickups to project the sound.

It uses a principle of electromagnetic induction to translate the movement of metal strings into a very small electric current within a set of pickups. These tightly wound magnetic coils are positioned directly under the area where the player strums and usually contain a set of six pole pieces that sit directly below each string. When the string is plucked it induces a voltage fluctuation inside the pickup, which is then channelled out of the instrument down a lead and into an amplifier. The wattage of the guitar amp largely defines the volume with big live acts using powerful 16-speaker stacks to achieve maximum loudness.

Players also boost the raw guitar signal with effects units or foot pedals that apply layers of distortion for achieving that distinctive crunching rock sound.

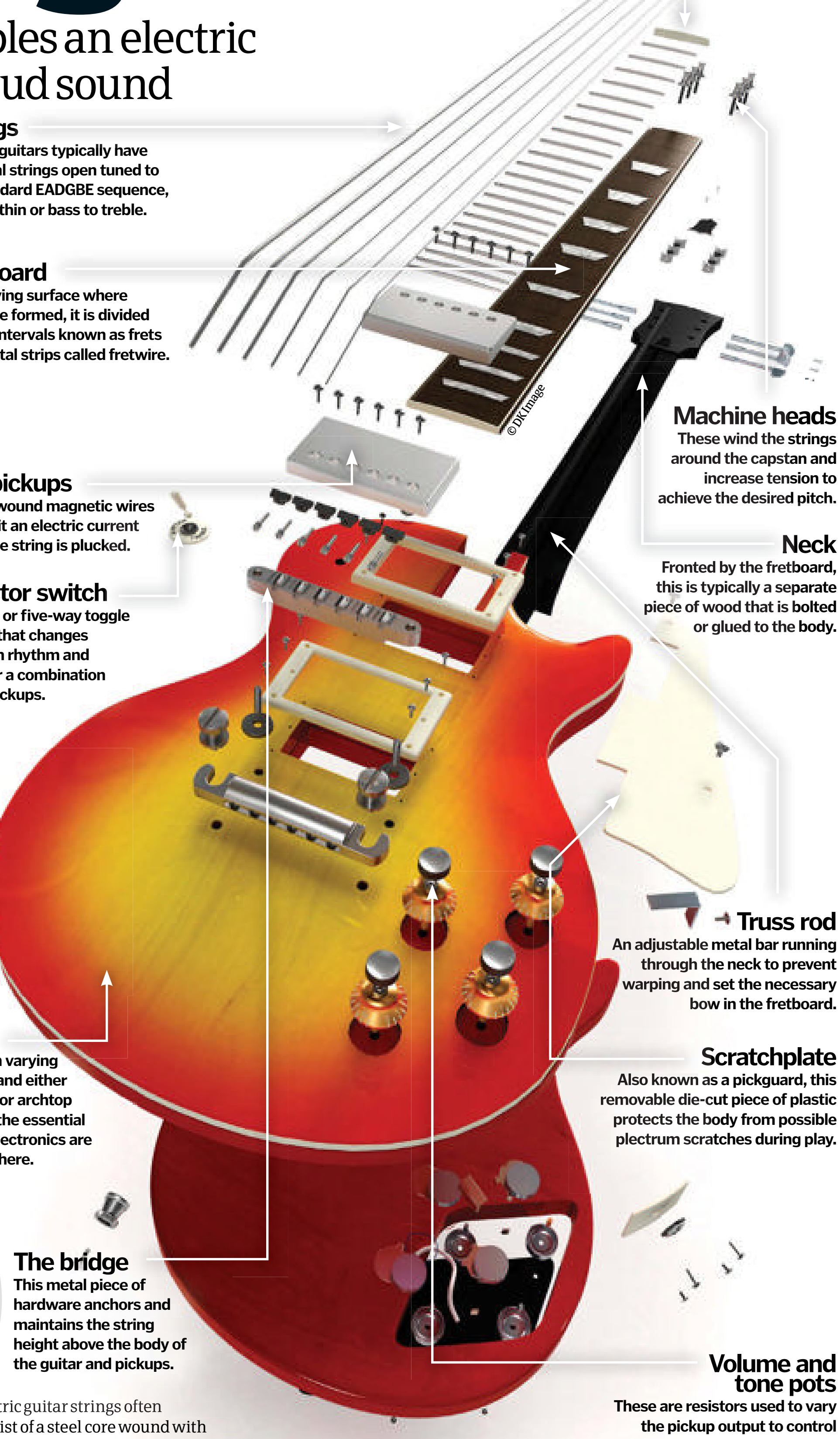
Wound for sound

We know that the vibrating steel strings generate an electric current within the pickups, but the frequency of this current is proportional to certain characteristics of the string itself. The wavelength of the oscillations change as the strings are plucked at various frets, and the player uses tension with the fretting hand to shorten the length of the string at each interval of the fret board. This changes the vibration pitch passing above the pickup to create the notes needed to form the chords. A thicker 'gauge' of string tends to offer a louder output and heavier tones, while factors such as how the string has been wound also influence the final sound.



© Science photo library

Electric guitar strings often consist of a steel core wound with nickel-plated steel wire



© DK Image

The nut
A strip of plastic or bone that saddles the strings from the headstock and down the neck to the bridge.

Strings
Electric guitars typically have six metal strings open tuned to the standard EADGBE sequence, thick to thin or bass to treble.

Fretboard
The playing surface where notes are formed, it is divided into 22 intervals known as frets with metal strips called fretwire.

Machine heads
These wind the strings around the capstan and increase tension to achieve the desired pitch.

The pickups
Tightly wound magnetic wires that emit an electric current when the string is plucked.

Neck
Fronted by the fretboard, this is typically a separate piece of wood that is bolted or glued to the body.

Selector switch
A three- or five-way toggle switch, that changes between rhythm and treble or a combination of the pickups.

Truss rod
An adjustable metal bar running through the neck to prevent warping and set the necessary bow in the fretboard.

Body
Found in varying shapes and either of a flat or archtop profile, the essential guitar electronics are located here.

Scratchplate
Also known as a pickguard, this removable die-cut piece of plastic protects the body from possible plectrum scratches during play.

The bridge
This metal piece of hardware anchors and maintains the string height above the body of the guitar and pickups.

Volume and tone pots
These are resistors used to vary the pickup output to control volume and tone for each pickup.

Inside the Xbox 360

Xbox has become one of the industry standards for console gaming, but what makes this machine work?

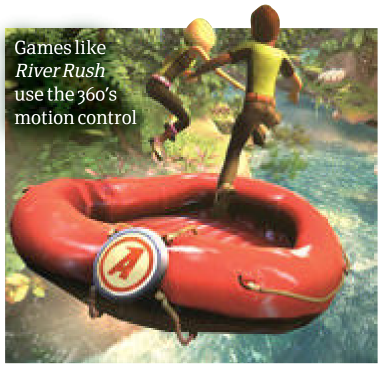
XBOX 360
XBOX 360
XBOX 360
KINECT

While the latest version of the Xbox, the Xbox 360 S, is no faster than its predecessor, it's still fascinating to see how the console has been upgraded. For starters it only needs a 135 watt power supply, and uses two cooling fans instead of one. These factors combine to make the 360 S both quieter and cooler. It is also smaller and more versatile than its predecessor.

The 360 S ships with Kinect, Microsoft's motion control system that uses an infrared sensor and a multi-channel microphone to allow a player to act as their own controller, with the system monitoring your movements. It also has five USB ports, which not only makes the unit more versatile and eliminates the need for external hubs, but also allows the old Xbox Memory Units to be phased out.

The biggest changes, however, are actually found inside the casing. The standard unit now ships with a 250GB internal hard drive which – while still removable – is a different design to its predecessors. The 360 S also comes equipped with built-in Wi-Fi, meaning that it can connect to a home hub and access Xbox Live very easily.

All of these features, combined with the Kinect system, make the 360 S a very powerful addition to the Xbox family and one that looks set to be the benchmark for improvements to come.


Games like *River Rush* use the 360's motion control

The end of the Red Ring of Death?

The Red Ring of Death refers to a ring formed by three status lights on the front of the machine. Normally green, if they go red it's usually because of either power fluctuations or by overheating damaging the motherboard, which will need to be replaced. Now, though, the Red Ring is no more according to Microsoft. This has been achieved by replacing the original 360's single fan with two smaller ones, making the machine quieter but also keeping it cooler.

A sight many Xbox owners have been too familiar with in the past

Head to Head

Innovative controllers

OLD

1. EyeToy

Released back in 2003, the PlayStation 2 motion control system needs a brightly lit room to work effectively, but has proved popular.

NEWER

2. Wii Remote

Originally designed to be used with the GameCube, the 'Wiimote' and nunchuk have helped popularise motion-control gaming.

NEWEST

3. PlayStation Move

This clever little system measures the unit's orientation relative to the Earth's magnetic field to work out how it's being moved.

DID YOU KNOW? *Microsoft's Kinect motion-control system has achieved over 10 million sales*

Gaming in motion

Kinect is Microsoft's new take on motion control. Containing a camera, depth sensor and multi-array microphone, Kinect allows a player tremendous freedom of movement.

The depth sensor throws an infrared 'net' out into the room which allows the sensor to sense not only that you're moving, but where in the room you are, and can be adjusted to take into account the size of the room and any obstacles. This sensor field means Kinect can track up to six people, including two active players, and pick up on movements in 20 joints per player.

Kinect's microphone also allows it to locate the player in the field, allowing for headset-free chat over Xbox Live.

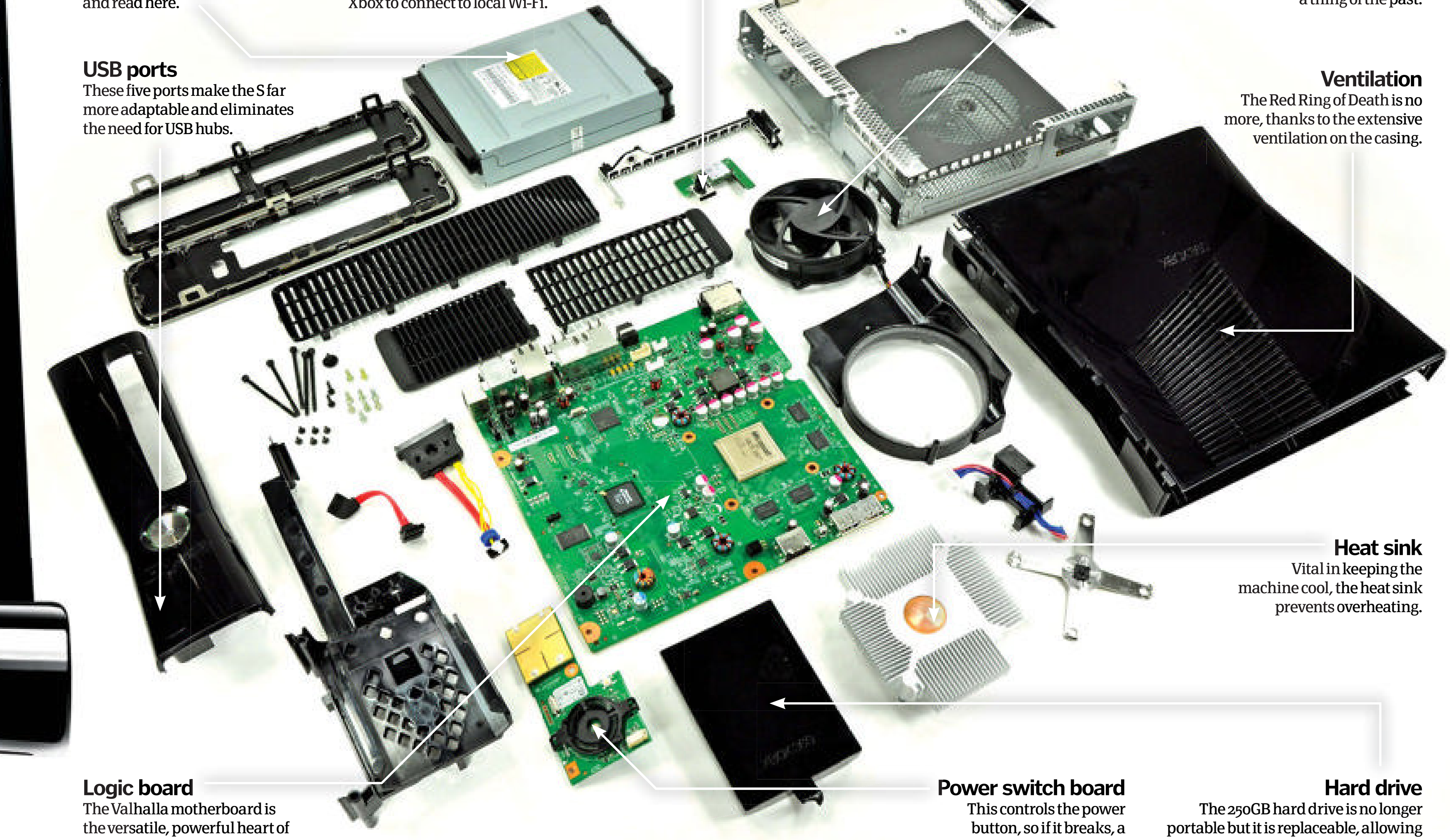
Kinect brought motion control to the Xbox 360 masses

The Statistics

Xbox 360 S

Manufacturer: Microsoft
Dimensions: 264 x 75 x 209mm (10.4 x 3.0 x 8.2in)
Weight: 4kg
Processor/speed: 500MHz
Unit price UK/US: £189.99/$299.99
Memory: 250GB
Power: 135w
Graphics: 16:9 ratio widescreen and high definition
Sound: 48kHz 16-bit audio

Xbox 360 anatomy



Optical drive
The games and movies are loaded and read here.

Wi-Fi board
Plugged into the machine's internal USB port, it allows the Xbox to connect to local Wi-Fi.

Fan
The S is much better ventilated than its predecessor, hopefully making the Red Ring of Death a thing of the past.

USB ports
These five ports make the S far more adaptable and eliminates the need for USB hubs.

Ventilation
The Red Ring of Death is no more, thanks to the extensive ventilation on the casing.

Heat sink
Vital in keeping the machine cool, the heat sink prevents overheating.

Logic board
The Valhalla motherboard is the versatile, powerful heart of the Xbox 360 S.

Power switch board
This controls the power button, so if it breaks, a replacement is a must.

Hard drive
The 250GB hard drive is no longer portable but it is replaceable, allowing you to upgrade if needed.

The hard drive

The major change with the 360 S is that the hard drive can't be pulled out and dropped into another Xbox 360. It can be removed, but the process is a lot more involved. While this cuts down on the system's portability and versatility, it's balanced by the fact the hard drive is replaceable and upgradeable. Microsoft's 4GB version is available and can be upgraded to the 250GB hard drive separately, at a later date.

Learn more

For more info and images of the exposed Xbox 360 S, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.

"No longer was music trapped in the present. Now it could be recorded, stored and replayed in the future"

Audio reproduction

Since the creation of the phonograph in the late 19th Century, sound reproduction systems have evolved massively, culminating in the hi-tech audio and loudspeaker systems we use today

© Monitor Audio

The recording and reproduction of audio underwent sweeping changes throughout the late 19th and 20th Centuries, offering many different new storage mediums, playback systems and methodologies that enabled humans to control the sound wave like never before. At first relying upon mechanical inscription and re-creation techniques, before advancing onto electrical methods, the analogue and digital recording of speech, music and environmental noise has brought sounds never before heard to the masses, as well as creating two of the most dominant entertainment business on the planet, music and film.

Indeed, when the phonograph (the earliest form of audio recording and reproduction system, partnered with a horn loudspeaker) was first invented in the latter half of the 20th Century, it advertised a system that could 'transport you to the realms of music' and that it could 'bring the theatre or opera to your home' after a hard day's work. It was a revelation. The sound wave had been captured and harnessed by man. No longer was music and speech trapped in the present. Now it could be recorded, stored and replayed in the future. Higher forms of musical entertainment were no longer the reserve of only the rich and powerful, with the best opera and ballet scores transported to the homes of many.

Since that momentous invention techniques and machines used to record and reproduce audio have progressed rapidly, and with them have the loudspeakers necessary to output their signals. Most early phonographs or gramophones used horn loudspeakers, which acted like modern-day amplifiers, and worked by increasing the coupling efficiency (akin to increasing the surface area of an object) between the system's driver, which was often a small metal diaphragm, and the surrounding air. This mechanical amplification effectively increased the volume of the outputted vibrations emanating from the diaphragm, and made the sound audible to listeners over a wider area.

Now, of course, amplification is normally achieved through electrically driven amplifiers, and the complex loudspeaker systems in use today rely on more than just spreading the surface area of sound waves. Here we take a closer look at how modern loudspeakers work.

History of audio systems

Audio systems have evolved massively since their creation in the late 19th Century

Cylinder phonograph

Date made: 1877

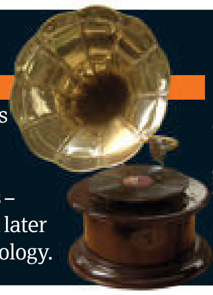
By rotating cylindrical records on which audio was engraved, these engravings would, via the medium of a stylus, vibrate a diaphragm at the base of a metal horn, which would in turn amplify the sound.

© Holger Ellgaard

Gramophone

Date made: 1892

Gramophones read the grooves in the circular disks by their needle – like the cylindrical phonograph did with its stylus – amplifying sound by horn and later electronic amplification technology.



© HGeorges Jansoone

5 TOP FACTS SPEAKERS AND AUDIO

Feel the base

1 At 190 decibels the human eardrum has a 50 per cent chance of rupturing, and this can result in loss of hearing and take weeks before the eardrum heals completely.

Maximum power

2 The world's loudest speaker is the Wyle Labs' WAS 3000, which can produce a sound level of 165 decibels, around the same as a space shuttle taking off.

Do you retro?

3 The last mass-market cylindrical phonograph record was produced as late as 1929, while today they are still made by specialist audio companies for collectors.

Crossed channels

4 During WWII the residents of Dover reported that they could hear the sound waves emanating from warfare across the channel in France, a distance of 21 miles away.

Can't keep it down

5 Despite the dominance of the CD, over 1.8 million vinyl records were sold in the United States in 2008, an increase of over 800,000 from 2007.

DID YOU KNOW? *German scientist Johann Philipp Reis created the original loudspeaker in 1861*

How a speaker works

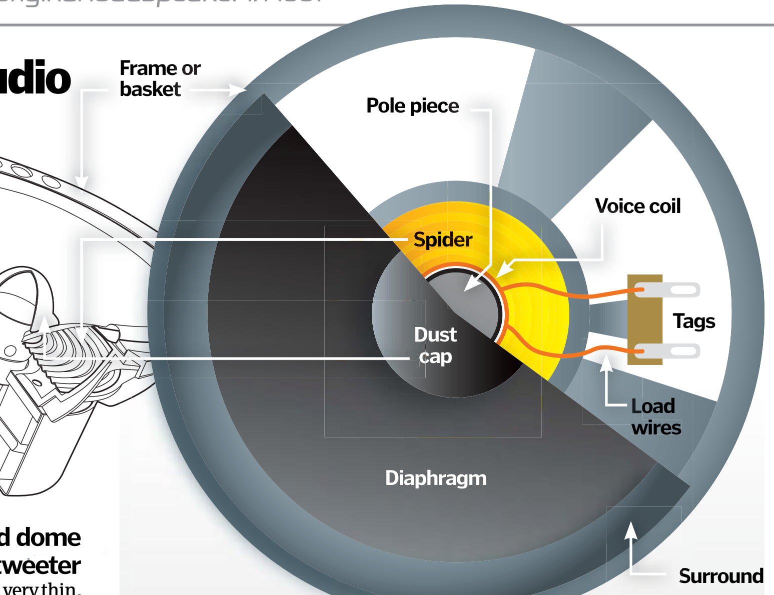
Even the clearest of recordings are useless without a good loudspeaker

The modern loudspeaker, as demonstrated by the Monitor Audio Apex series, produces sound by converting electrical signals from an audio amplifier into mechanical motion, from which sound waves emanate. Loudspeakers can consist of an individual transducer (audio driver) or a series of drivers encased within a large chassis, each dealing with a certain frequency band to improve the overall gamut and fidelity of reproduced sounds.

For example, larger subwoofer speakers deal with low frequencies, while smaller speakers called tweeters deal with high frequencies. These various drivers are controlled by a filter network, which organises the different frequency signals coming from the amplifier and directs them to the driver most suitable to deal with it.

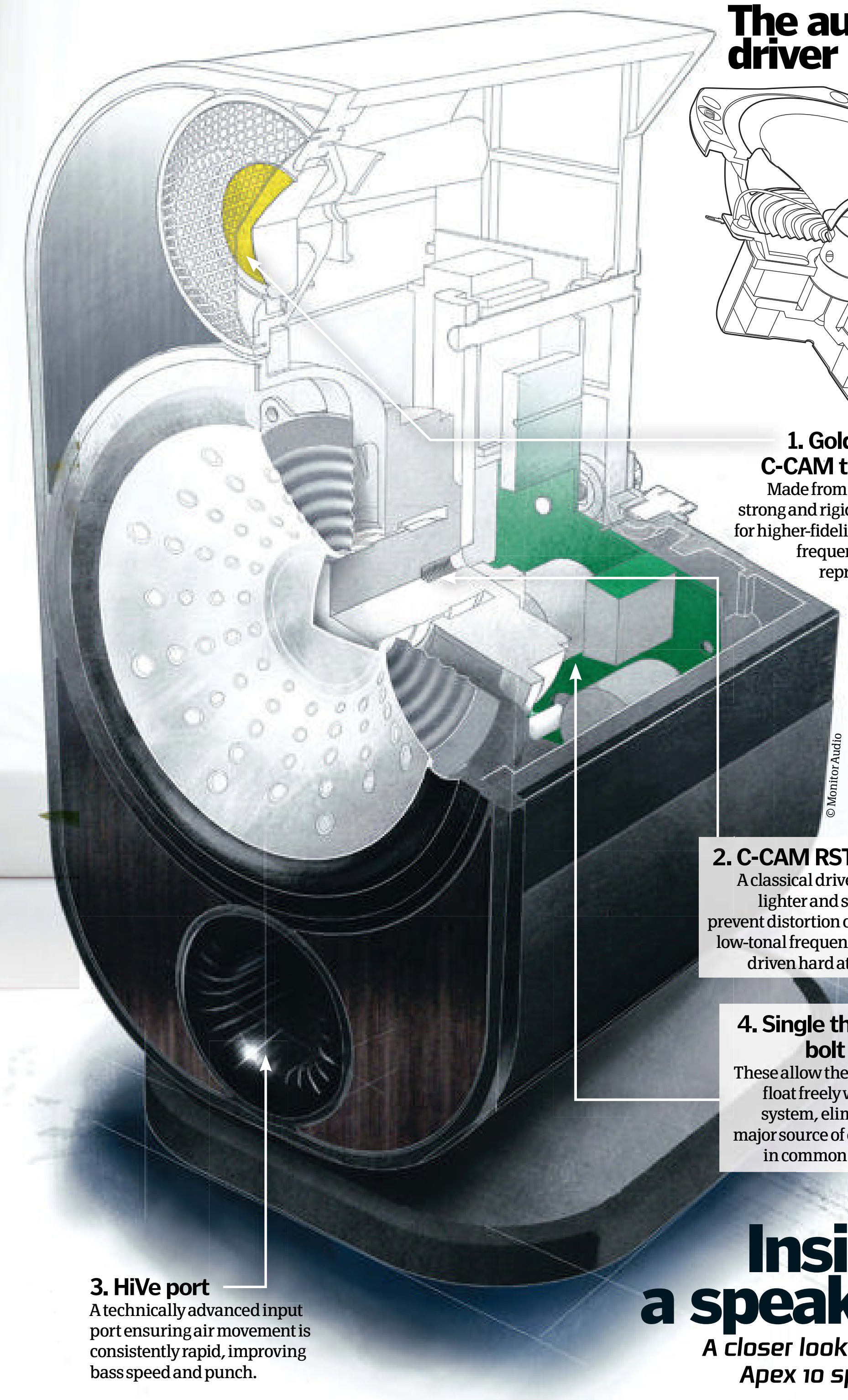
The construction of a single loudspeaker driver is a complex process, the central element of which is a concave plastic or paper conical disc. This is the part that moves backwards and forwards in the generation of sound, fixed in the centre of a concave metal frame. Attached to the cone is a hollow cylinder of aluminium and a pair of wire coils suspended by a flexible fabric disc. These coils are attached to the amplifier and positioned inside a narrow cylindrical groove in the centre of a magnet. By doing this, every time a signal travels through the wires, the coil emits a magnetic field that pushes or pulls the cone backwards or forwards, forming sound waves.

The audio driver



Inside a speaker

A closer look at the Apex 10 speaker



© Monitor Audio

1. Gold dome C-CAM tweeter
Made from very thin, strong and rigid material for higher-fidelity of high-frequency sound reproduction.

2. C-CAM RST driver
A classical driver, though lighter and stronger to prevent distortion of mid and low-tonal frequencies when driven hard at its limits.

3. HiVe port
A technically advanced input port ensuring air movement is consistently rapid, improving bass speed and punch.

4. Single through-bolt fixings
These allow the drivers to float freely within the system, eliminating a major source of distortion in common speakers.

Tape player

Date made: 1950

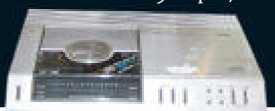
The invention of magnetic tape led to the creation of reel-to-reel tape players. Magnetic tape allowed large recordings to be stored for lengthy periods of time and done so in multiple takes.

© Nixdorf

CD player

Date made: 1982

With the introduction of compact discs, CD players took over as the dominant audio system. CD players work by rotating a disc between 200 and 500rpm, reading the encoded information contained on it with a laser beam.

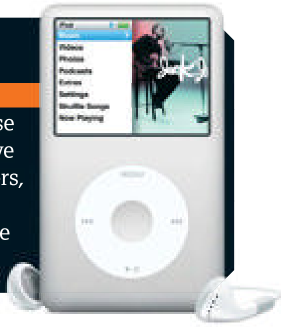


© Les Chatfield

MP3 player

Date made: 1997

The current player of choice, these work by converting an audio wave into a sequence of binary numbers, which can then be stored in a digital format such as MP3, before utilising audio codecs.



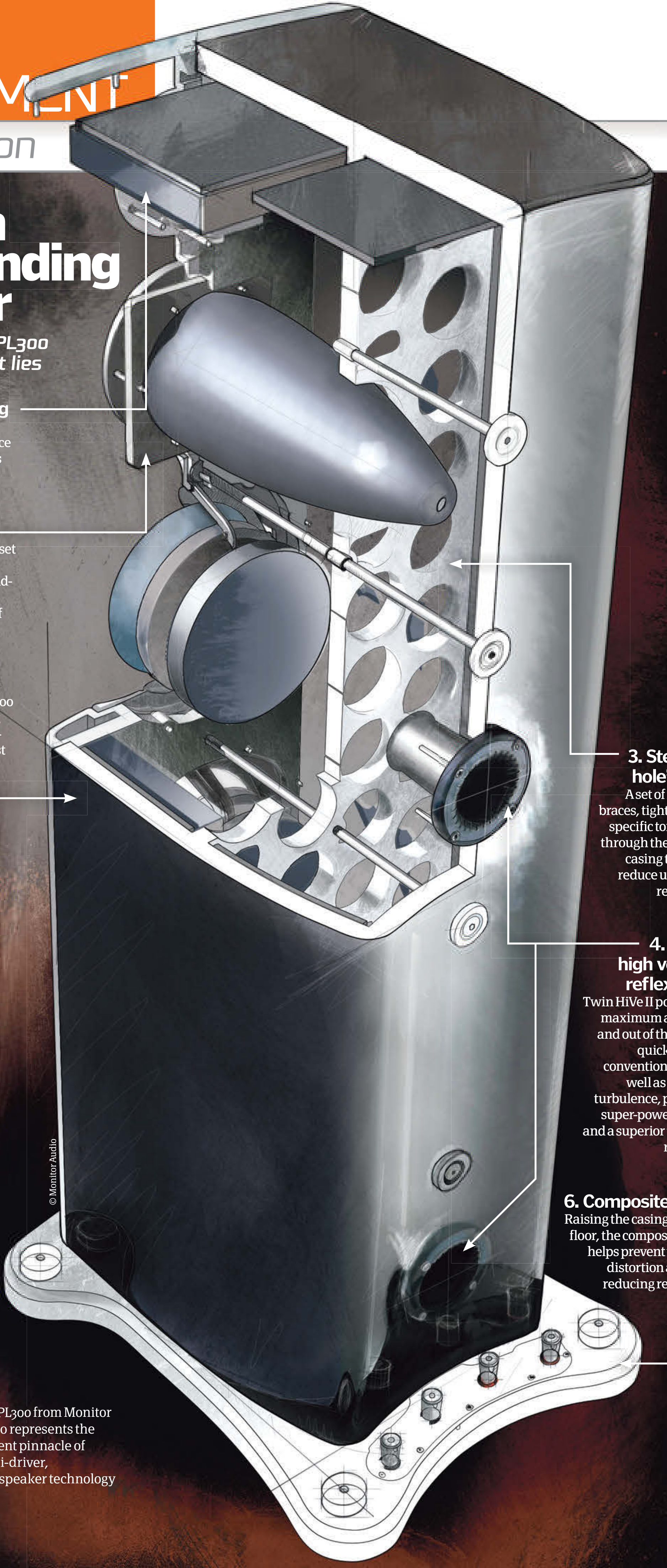
DID YOU KNOW?

Speaker placement can alter sound quality

Due to the fact that sound bounces off of the objects in your room, where you position your speakers will directly effect the quality of the sound that you hear. For instance, placing speakers too close to the wall will increase the bass sound, making it too loud or boomy. In general try to keep the speaker 7cm (3.0in) from the wall, the speakers' distance from the side wall should be 1.6 times the distance from the front wall. Angle the speakers inwards towards the general listening spot.

Inside a freestanding speaker

The Monitor Audio PL300 demonstrates what lies inside the cabinet



1. Bitumastic damping
This adhesive is applied to all internal cabinet walls to reduce resonance damping as well as aiding structural rigidity.

5. Tapered Line Enclosure (TLE)
Formed from an ARC thermo-set polymer, the Tapered Line Enclosure houses all of the mid-range drivers in the PL300, preventing the propagation of standing waves and modal resonances.

2. Polymer casing
Almost all elements of the PL300 loudspeaker's case, including front baffles, plinths and mid-range driver housings, are cast from a thermo-set polymer characterised by its high mineral content.

3. Steel 'pin hole' brace
A set of four steel braces, tightened to a specific torque, run through the polymer casing to further reduce unwanted resonance.

4. HiVe II high velocity reflex ports
Twin HiVe II ports allow maximum airflow in and out of the cabinet quicker than a conventional port as well as reducing turbulence, providing super-powerful base and a superior transient response.

6. Composite plinth
Raising the casing from the floor, the composite plinth helps prevent vibration distortion as well as reducing resonance.

© Monitor Audio

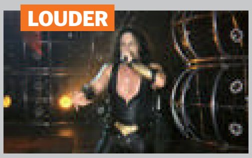
The PL300 from Monitor Audio represents the current pinnacle of multi-driver, loudspeaker technology

Head to Head LOUDEST BANDS

LOUD

1. The Who
Where: London, England
When: 31 May 1976
How loud: 126dB

LOUDER



2. Manowar
Where: Hanover, Germany
When: 8 March 1984
How loud: 129.5dB

LOUDEST

3. Kiss
Where: Ottawa, Canada,
When: 15 July 2009
How loud: 136dB

DID YOU KNOW? *The speed of sound varies depending on temperature and altitude*

Multi-driver loudspeaker enclosures

Floor-standing loudspeakers are now being produced which combine multiple audio drivers with audio-friendly, structurally complex cases

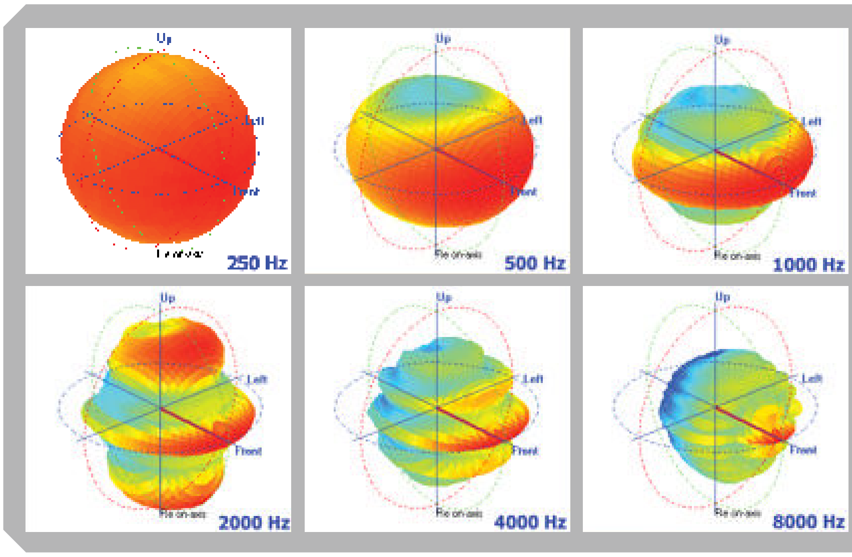
An example of an older, metal-framed, audio driver chassis

The enclosure of any loudspeaker plays a highly significant role in the reproduction of sound, as well as providing a unit in which the speaker's drivers, electronic circuitry, crossover control and amplifier are all mounted.

Current state-of-the-art enclosures are built from composite materials and include numerous struts, baffles air ports and acoustic insulation materials and adhesives. These work together to reduce echo and reverberation caused by rearward sound waves generated by the speaker's drivers reflecting off the back and sides of the case. This is important for audio fidelity and accuracy of reproduction, as rogue or errant sound waves can interfere with forward-generated waves, distorting them and adding effects not part of the original recording. The enclosure, thanks to its complex construction, is also the key factor in reducing vibrations caused by the back and forth movement of the driver diaphragm, shake of the driver chassis and rumble of any subwoofer.

Historically, in early forms of loudspeaker, drivers were often left exposed completely or partially due to heat-related issues with their electronics, as well as because of the fixed, unsuspended nature of the driver chassis and the difficulty in securing a consistent airflow. Further, the materials used in these early loudspeakers (usually heavy metals) were prone to vibration issues and did little to prevent standing waves, while their chunky and bulky designs caused diffraction of sound waves from their sharp edges.

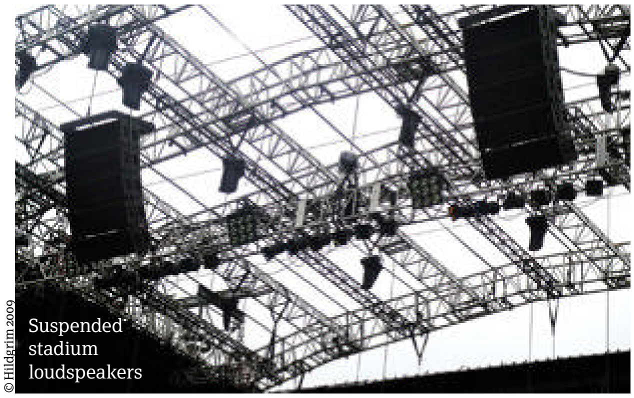
Today, these flaws are minimised by audio-friendly, lightweight polymer casing materials, which are manufactured with smooth edges to reduce refraction and coated with resonance and vibration damping adhesives. Single component plinths, baffles and struts, as well as lightweight driver chassis also aid the accuracy of sound reproduction and, thanks to the inclusion of transmission lines (an internal structure within the loudspeaker enclosure designed to guide up to 90 per cent of a driver's rear wave output away from distortion-prone areas) in modern cabinets, has allowed sleeker and more compact driver arrays.



Polar frequency patterns

Frequency has dynamic effects on loudspeakers

Composite images of six loudspeaker polar patterns taken at six frequencies over a five octave range. The speaker is a Bosch 36 watt column with four 10cm drivers arranged in a columnar enclosure 84cm high. The Polar prediction software used is CLF viewer and loudspeaker info was gathered by the manufacturer.



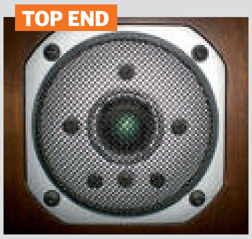
Suspended stadium loudspeakers

© Hilderim 2009

Where does he put the luggage?

Head to Head SPEAKER DRIVERS

TOP END



1. Tweeters

Tweeters are much smaller units, designed to produce the highest frequencies typically from around 2,000Hz to 20,000Hz. Some tweeters can manage response up to 45kHz. Nearly all tweeters are electrodynamic drivers, using a voice coil suspended within a fixed magnetic field. The name is derived from the high-pitched sounds made by birds.

MIDDLE

Asim18

2. Midrange

As the name suggests, midrange drivers produce a range of frequencies in the middle of the sound spectrum, with a frequency range from approximately 300-5,000Hz. Midrange drivers handle the most significant part of the audible sound spectrum. For this reason the midrange speaker must be good quality or discrepancies will be heard.

BASS IN YER FACE

3. Woofer

Designed to produce low frequency sounds, typically from around 40Hz up to about 1KHz or higher. The most common design for a woofer is the electrodynamic driver, which typically uses a stiff paper cone, driven by a voice coil which is surrounded by a magnetic field. The voice coil is attached by adhesives to the back of the speaker cone. Woofers are generally used to cover the lowest octaves of the system's frequency range although subwoofers are also sometimes employed.

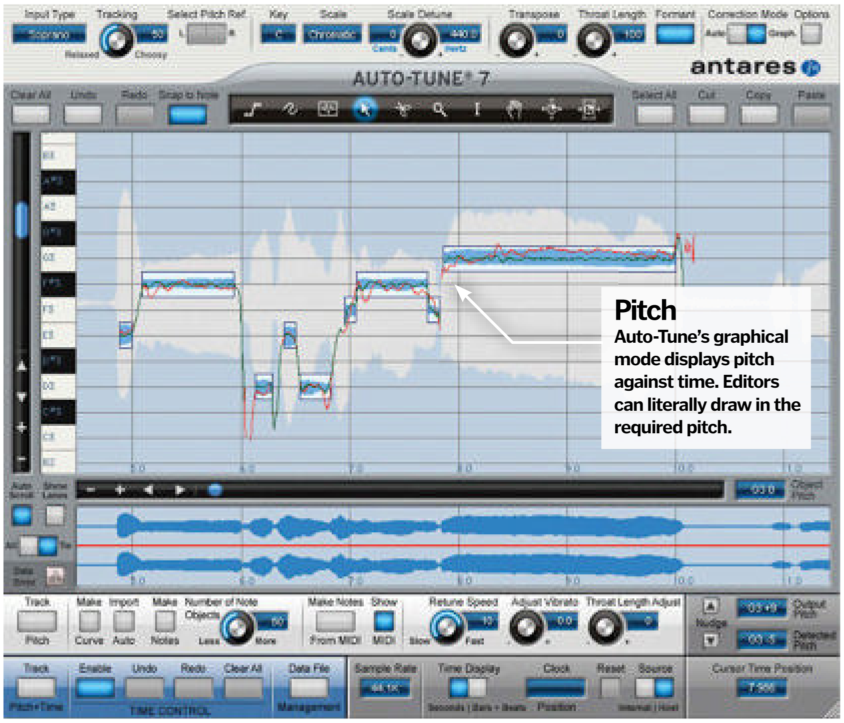
How Auto-Tune improves vocals

If you're more Robin Williams than Robbie Williams, technology can now give your voice the X-factor

ITV was criticised in 2010 for 'auto tuning' contestants' voices on *The X Factor* singing audition programmes. The technology is employed to tweak dodgy vocals into the polished sound we now expect on TV, but how does it work?

Auto-Tune is the brand-name of the pitch-correction software from Antares. Once the key and scale of a recording are set (by the sound editor or by the software), Auto-Tune analyses every note for deviation from target notes in the required scale. For off-key notes, the frequency of the output signal is altered so the pitch is corrected but the recording retains the voice's characteristics.

This technology is now used in most commercially recorded music and used well, it's undetectable. Bad auto-tuning can be heard as bubbly or jagged changes in pitch. Best results are achieved by only tuning obviously off-key notes, rather than the whole recording. Now, if only they could work out how to add the software to karaoke machines…


Input Type
Soprano
Tracking
Relaxed
Choosy
Select Pitch Ref.
Key
C
Scale
Chromatic
Scale Detune
Cents
Hertz
440.0
Transpose
Throat Length
Formant
Correction Mode
Auto
Graph
Options
antares
AUTO-TUNE® 7
Clear All
Undo
Redo
Snap to Note
Select All
Cut
Copy
Paste
Track
Pitch
Make Curve
Import Auto
Make Notes
Number of Note Objects
Less
More
Make Notes From MIDI
Show MIDI
Retune Speed
Slow
Fast
Adjust Vibrato
Throat Length Adjust
Nudge
Output Pitch
Detected Pitch
Enable
Clear All
Data File
Management
Sample Rate
Time Display
Seconds | Bars + Beats
Clock
Position
Reset
Source
Internal | Host
Cursor Time Position
TIME CONTROL

Pitch
Auto-Tune's graphical mode displays pitch against time. Editors can literally draw in the required pitch.

© Antares Audio Technology

IMAX cinemas

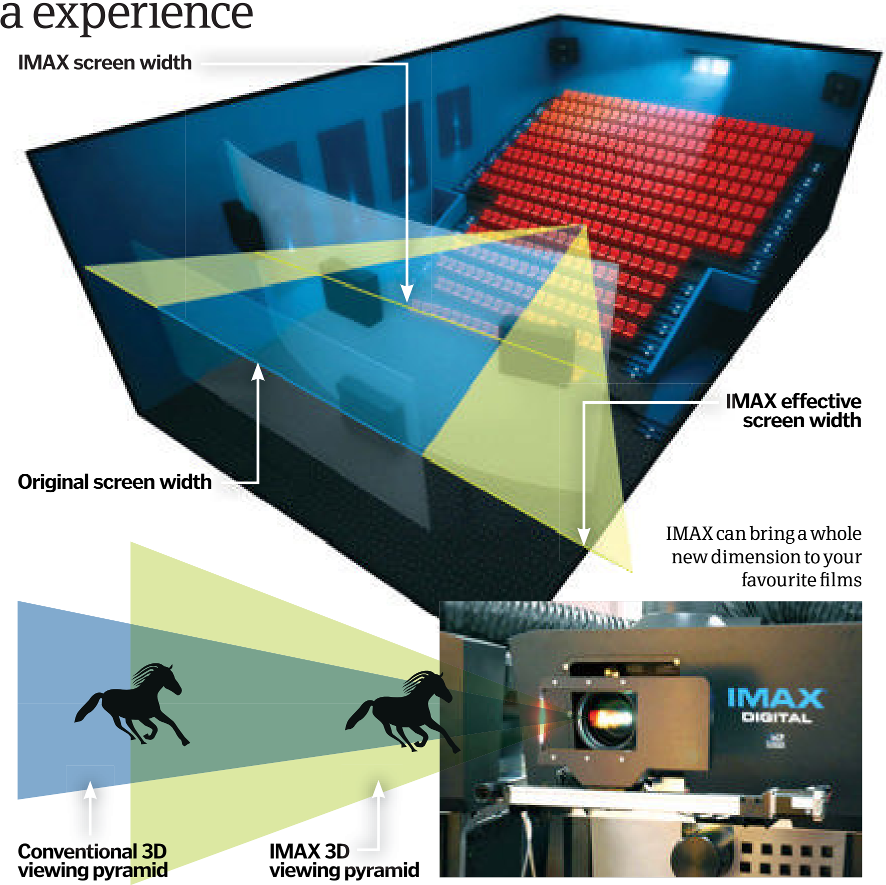
Making the cinema experience as real as possible

The IMAX system uses 70mm film, with 15 perforations per frame that runs horizontally rather than vertically through the cinema projector. It is ten times larger than standard 35mm film. That means huge 109kg cameras are needed to film IMAX movies. They can only shoot three minutes' worth of film at a time and take 20 minutes to reload.

IMAX cinemas employ a two-ton projector with a 15,000 watt lamp and a vacuum system to keep the film in alignment with the lens.

The IMAX screen is far larger than a normal screen and is positioned in the cinema to maximise audience field of view. It has a special coating of silver paint to enhance the brightness of the picture, and has thousands of perforations to allow sound to pass through it.

Furthermore, each film has a specially mastered soundtrack that is compatible with the IMAX digital audio cinema system, so that each spectator enjoys clear and realistic sound as well as pictures.


IMAX screen width
Original screen width
IMAX effective screen width
Conventional 3D viewing pyramid
IMAX 3D viewing pyramid
IMAX DIGITAL

IMAX can bring a whole new dimension to your favourite films

5 TOP FACTS
IMAX MILESTONES

1 **The Dark Knight**
Released in 2008, this is the first major Hollywood movie to include sequences filmed by IMAX cameras. They amount to 30 minutes of screen time.

2 **Superman Returns**
The first live-action movie to have sequences of it converted from the normal 2D format to IMAX 3D format. 20 minutes is in 3D when viewers are cued to put on their 3D glasses.

3 **Polar Express**
This is the world's first IMAX 3D Hollywood movie. It was digitally remastered from the original 2D film. IMAX is now developing special 3D cameras for future live action releases.

4 **The Matrix Revolutions**
This was the first Hollywood blockbuster to be simultaneously released in conventional and IMAX theatres. The action sequences especially benefited from being converted into this high resolution format.

5 **Apollo 13**
In 2002, the new IMAX DMR technology is used for the first time to digitally remaster this conventional format Hollywood movie into the IMAX format. It was rebranded as *Apollo 13: The IMAX Experience*.

5 TOP FACTS SPECIAL FX

Animation
1 If the main characters in your story are toys, bugs or aliens, CGI or stop-frame animation with models are the best ways to bring them to life on screen.

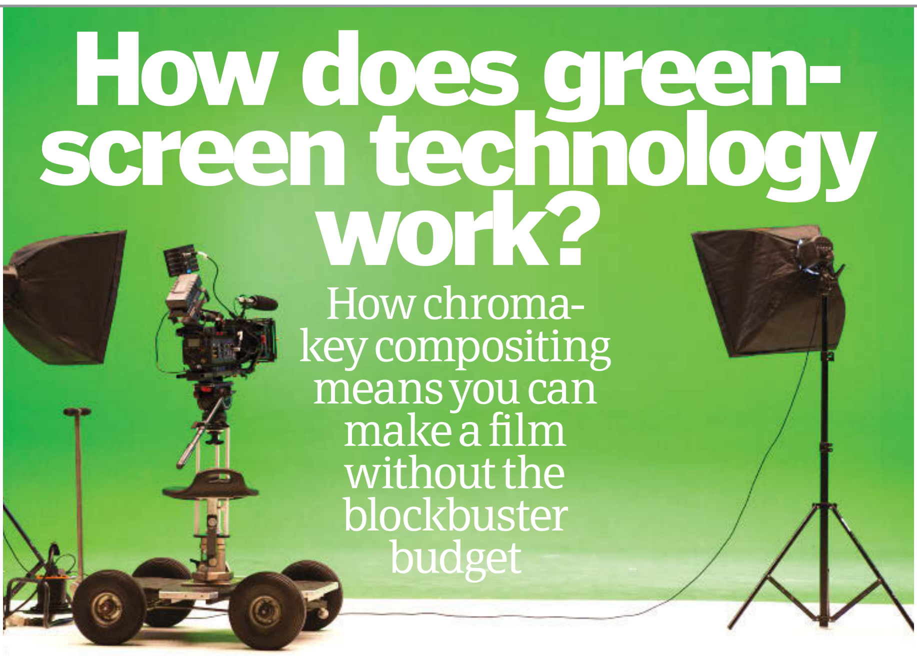
Compositing
2 You can create incredible scenes by trying your hand at compositing – removing a portion of a video clip and superimposing it over the top of a different clip.

Chromakeying
3 For flying stunts, imaginary worlds and weather forecasts, the subject is filmed in front of a greenscreen. The green area is digitally removed by the editor who adds a background.

Perspective trickery
4 Want an actor or object to appear larger in relation to the rest of the scene? Simply place him/her/it nearer to the camera, and play around with the viewer's perspective.

Physical effects
5 It's not always about the digital – sometimes it's more convincing to use good old-fashioned prosthetics, gory make-up, pyrotechnics and miniature models.

DID YOU KNOW? Universal Studios in LA claims to have the world's largest greenscreen – it's 12m x 24m



How does greenscreen technology work?

How chroma-key compositing means you can make a film without the blockbuster budget

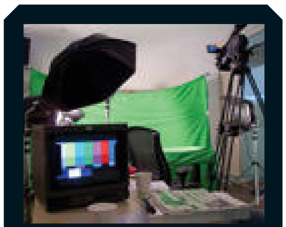
There's no need to jet off to exotic locations, fret about the weather or perform outrageous stunts – all you need is a large green sheet and a clever editor. Greenscreen trickery – also known in the business as 'chromakey compositing' – has been used in the broadcasting and entertainment industries for decades. The first step of the technique is to film the 'talent' (actor or presenter) in front of a large block-colour background. Next, the colour has to be deleted in the editing room. Last, the compositing is completed by adding the chosen background, which could be anything from a twinkling cityscape or informative weather map to an alien planet or a thrilling rollercoaster ride.

The set up is vital: the screen must be stretched tight and lit evenly, so it appears as a uniform colour on camera. The talent is lit separately, to match the composited background. For example, if they will be superimposed on a bright outdoor scene, a powerful lamp is rigged above them.

But why use green in favour of a handy white or black wall? Editing software removes all of the key colour in the frame. Most compositing tasks involve filming human subjects and because people rarely have shades of green in their skin tone, it's the best colour to use. To capture authentic natural light, directors sometimes shoot greenscreen action outdoors; a blue screen wouldn't work here, because the software might erase bits of the sky.

For live weather forecasts and news reports, the chromakey filter is applied as the images are broadcast, with the presenter and director able to see the background behind the talent in their monitors.

If you're not a filmmaker, you can still use the chromakey function in photo-editing software to give snapshots the Hollywood treatment. The only limit is your imagination, but first you'll need to find a green sheet…



In the edit suite

Modern video-editing software makes greenscreen effects simple with the chromakey function. Load the clip with the background video on a channel underneath it. Apply the Chroma Keyer filter to the clip and then use the Eyedropper tool to select the green colour of the background. The software then takes away all the pixels in that shade of green from the entire frame throughout the whole video clip. The background video can now been seen through the missing pixels.

Editing skill is needed in the fine-tuning: first, adjust the Tolerance – increase it to remove a wider range of green shades. The Soften and Enhance sliders can be used to smooth the edges of the subject by feathering and mixing edges with the composited video.

Avoiding greenscreen goof ups

Some common greenscreen mistakes and how to avoid them

1. Pick the right colour

If the talent has blonde hair, blue might work better than green. Careful you don't delete their irises. Make sure the talent doesn't wear any clothes/make-up in shades close to the screen colour.

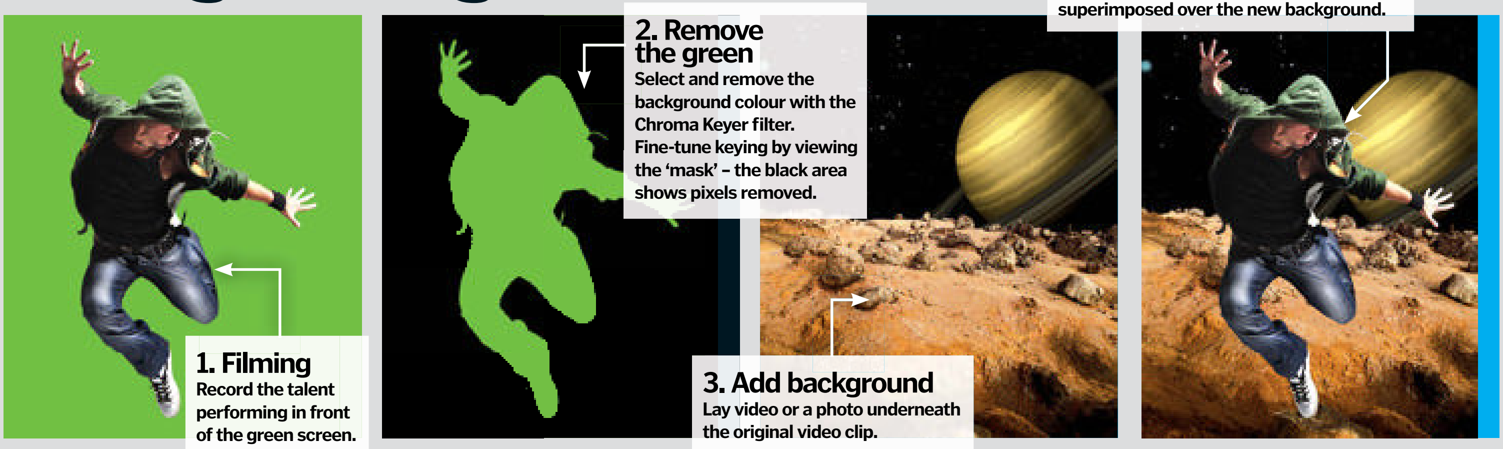
2. Light the screen and talent separately

The screen must be lit evenly with one lamp on each side. The talent must be lit separately to match the conditions in the composited background and ensure the screen colour isn't reflected onto them.

3. Be careful if you're live on air

A recent error occurred on American TV station KIDK's live news, when the gallery editor cut to the weather presenter without cutting the news presenter. The weather presenter appeared to be nuzzling the news presenter's ear!

Filming with a green screen



1. Filming
Record the talent performing in front of the green screen.

2. Remove the green
Select and remove the background colour with the Chroma Keyer filter. Fine-tune keying by viewing the 'mask' – the black area shows pixels removed.

3. Add background
Lay video or a photo underneath the original video clip.

4. Export composite video
With the green keyed out, the actor is now superimposed over the new background.

Inside a PlayStation 3

Sleek, slim, elegant – the PS3 is one of the most stylish pieces of videogaming kit on the market. But how does it work?

The heart of the PS3 is its hard drive. The starting hard drive is 120 gigabytes and it can be upgraded to 160, 250 or even 320 gigabytes, double the size of the largest hard disk in the original model.

The PS3 also takes advantage of advances in chip and CPU design, with the chip now able to be manufactured no larger than 60 nanometers. This reduction in size means the chips are more efficient, use less power and need less cooling, all of which means the PS3 generates less heat. This in turn means the bulky fan of the original could be scaled down, shrinking the casing and allowing the unit's slimline look.

The unit's Blu-ray player is the other vital piece of equipment. Blu-ray DVDs use a shorter wavelength laser (which is actually violet, rather than blue), allowing five times more information than a standard DVD to be stored on the disc. The PS3 can also read CDs and normal DVDs but backwards compatibility has been removed, meaning that the unit is the first one in the line to not be able to play PS2 games – although, oddly, it can still read PlayStation 1 games.

The PS3 is also the first version of the unit to be free of the 'leap year bug'. This was discovered on 1 March 2010, when a large number of PlayStation users found themselves unable to sign into the PlayStation Network, play games or use trophies and dynamic themes. The problem was eventually traced to the unit's internal clock, which measured the date in binary and viewed the year 2010 as a leap year. The mistake was corrected in an update to the system software, released on 29 June 2010.

Motion controlled and in control

The Sixaxis controller replaced the vibrating sensors of the old PS2 controllers with motion control sensors that measured the orientation of the controller across six axes. This in turn is transmitted back to the PS3 using Bluetooth technology. The controllers could also be used to control the PSP Go, but it had to be connected via a USB cable. The Sixaxis was replaced in 2009 by the wireless DualShock 3 controller, which incorporated its motion control features.

Head to Head
PS3'S OTHER COOL USES

COOL

© SCEE

1. TV catch-up
TV catch-up services are everywhere now, and the PS3 is no exception. It allows you to catch up on your favourite shows through streaming video.

COOLER

© SCEE

2. Life with PlayStation
As well as allowing photo and video playback, this features news, historical interest sites and articles from across the world.

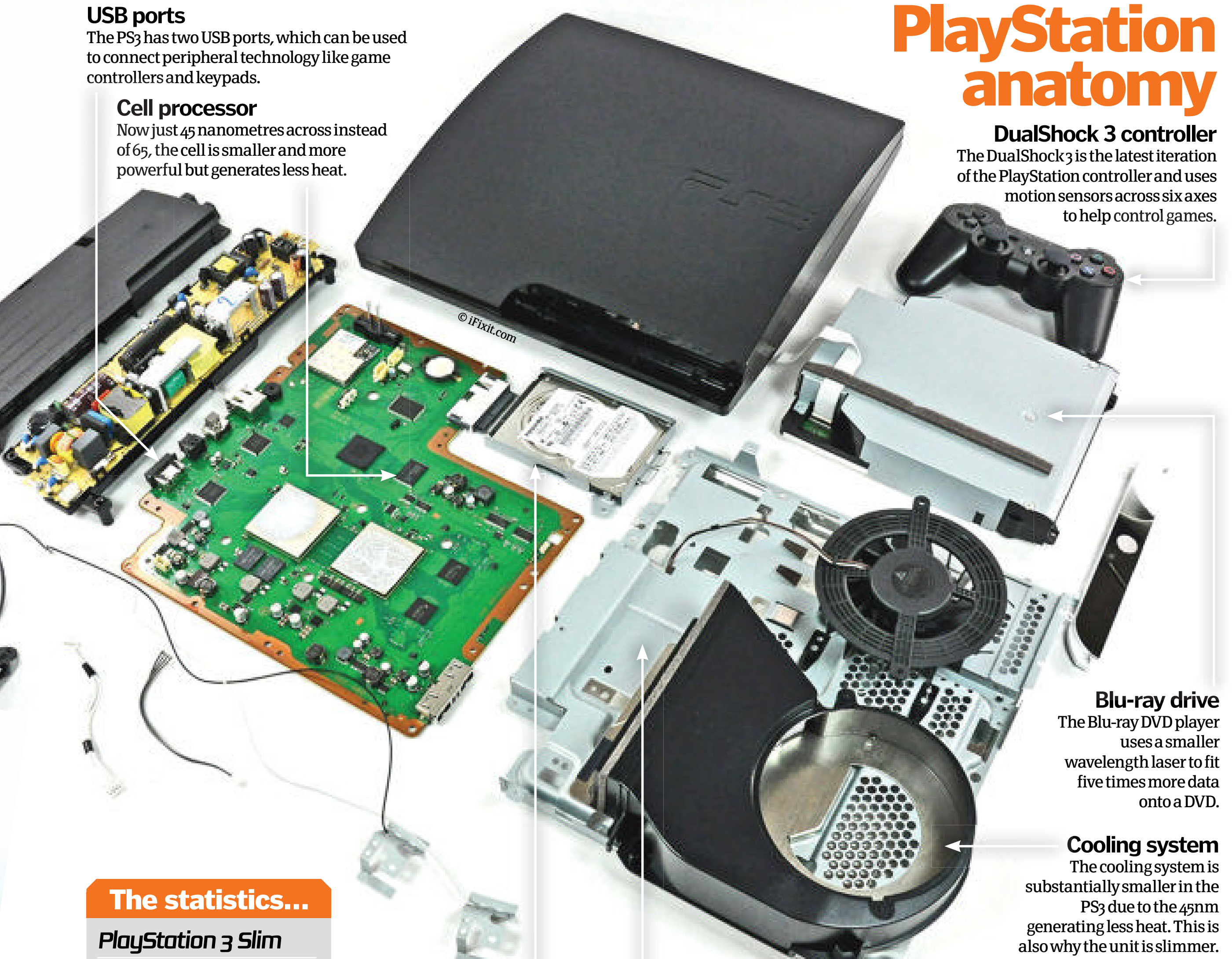
COOLEST

© SCEE

3. Blu-ray movies
The PS3's incorporation of the high-quality Blu-ray disc player was influential in signalling the end of the HD DVD format.

DID YOU KNOW? A new PlayStation logo is being rolled out on the PS3 – the old one used the same font as the Spider-Man films

PlayStation anatomy


© iFixit.com

USB ports
The PS3 has two USB ports, which can be used to connect peripheral technology like game controllers and keypads.

Cell processor
Now just 45 nanometres across instead of 65, the cell is smaller and more powerful but generates less heat.

DualShock 3 controller
The DualShock3 is the latest iteration of the PlayStation controller and uses motion sensors across six axes to help control games.

Blu-ray drive
The Blu-ray DVD player uses a smaller wavelength laser to fit five times more data onto a DVD.

Cooling system
The cooling system is substantially smaller in the PS3 due to the 45nm generating less heat. This is also why the unit is slimmer.

Hard drive
The PS3's hard drive can be upgraded from 120GB to 160GB, 250GB or 320GB, far larger than the previous model's maximum memory size.

Power supply
Due to the smaller cell processor the PS3 draws less power, resulting in a smaller power supply than in previous models.

The statistics...

PlayStation 3 Slim

Manufacturer: Sony

Dimensions: 33cm x 10cm x 25cm (12.9in x 3.9in x 9.8in)

Weight: 5kg

Processor/speed: 3.2GHz

Unit price UK/US: £255.30/$300.00

Memory: 120, 160, 250 or 320GB (upgradable)

Display: 480i, 576i (PAL), S-Video 480i, 576i (PAL) RGB SCART 480i, 576i (PAL), Component (YPBPR) 480i, 576i (PAL), 480p, 576p, 720p, 1080i, 1080p, D-Terminal 480i, (DI), 480p (D2), 720p (D4), 1080i (D3), 1080p (D5) and HDMI 480p, 576p, 720p, 1080i, 1080p

Graphics: 550MHz NVIDIA/SCEI RSX 'Reality Synthesiser'

Sound: A/V Multi, Analog Stereo, Through TOSLINK; LPCM, (two channels), Dolby Digital 5.1, DTS 5.1 AAC, through HDMI; LPCM, DTS-HD Master Audio Bitstream, Dolby TrueHD Bitstream, Dolby Digital 5.1, DTS 5.1 and AAC

> "The PS3 can read CDs and normal DVDs, but backwards compatibility has been removed"

Social networking

The PS3 uses Remote Play to tie in with your PSP. Remote Play transmits a live video stream of the output from the PS3 to your PSP over Wi-Fi and in turn transmits actions from the PSP back the same way, allowing you to use your PSP as a controller. This system also allows for all manner of in-game uses, such as acting like a rear view mirror in driving games. The PS3 also checks for – and installs – system software updates if it's connected to an active Wi-Fi network.

Bluetooth allows for up to seven wireless controllers and the Bluetooth system is used for peripherals like headsets for players in different locations.

Learn more

For more information and images of the exposed PS3 Slim, visit the gadget surgeons at **ifixit.com** who kindly contributed photos and findings for this article.

The PS3 Slim's prized Blu-ray drive

© iFixit.com

Two USB ports allow peripherals to be connected

© iFixit.com

INTERNET TV

hulu
ETFLIX
tv
BBC
iPlayer
Virgin
me
SAMSUNG

High-definition TV in your living room? Internet to the rescue!

More choice and freedom should suit the whole family

Ordinary television programmes today are broadcast from videotape as an analogue UHF radio signal that is picked up by your TV aerial. This system distributes the signal across the whole country, virtually simultaneously, and according to a fixed schedule.

Streaming TV programmes across the internet turns this approach on its head. Suddenly, each user could be downloading a different programme at an arbitrary time and in a variety of resolutions and formats.

Programmes destined for streaming are first digitised to a master file at the highest possible quality. This is compressed using algorithms that discard information that doesn't change from one frame to the next, or which doesn't contribute very much to our subjective impression of the picture quality. Our eyes are much less sensitive to blue wavelengths of light than red ones, for example, so a video stream uses fewer bits to encode the blue channel than the green and red. A programme might be compressed at several different resolutions to allow for viewing on mobile phones, as well as standard and high-definition TVs.

When you send something over the internet, it is split into little pieces called 'packets'. Each packet is put in a sort of digital envelope, using a protocol called TCP/IP, with the destination address and

5 TOP FACTS BBC iPLAYER

Mobile viewing
1 iPlayer usage on mobiles peaks after midnight, as teenagers sneakily watch under the covers. There's also a peak at the weekend, on Saturday and Sunday mornings (8am-10am).

Server power
2 The BBC uses a total of 60 servers to encode its programmes for iPlayer. More than 400 hours of programmes are converted each week.

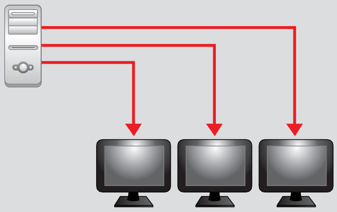
Essential delay
3 If your programme isn't available on iPlayer the instant it has finished broadcasting, that's usually because it was broadcast live. It takes about an hour to process the tape.

Bandwidth
4 The iPlayer shifts more than seven petabytes of web traffic every month; that's seven million gigabytes, or approx. 7,000,000,000,000,000 bytes. That's a lot of bytes!

Stream count
5 BBC iPlayer handles around 117 million stream requests a month across all platforms, including the iPlayer service on Virgin Media TV.

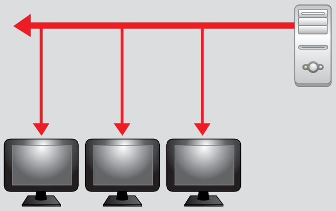
DID YOU KNOW? *You don't need a TV licence if you only watch programmes on iPlayer or 4oD after they have been broadcast*

Delivery explained



Unicast transmission

The standard method of transmission on the internet uses a single destination address for each network packet. The network carries each packet from router to router until it reaches the addressee.



Multicast transmission

With multicasting, a network packet carries a list of addresses or a numerical range. This packet only leaves the server once and travels as before, except that the routers along the way will automatically clone the packet as required to send it to all of the destination clients.

instructions for how to assemble it at the other end. The packets all travel independently and may go by different routes, according to how busy the individual computers are that they encounter along the way. This system is very good for making sure that a file eventually arrives in one piece, but it is terrible for streaming video. If there is a minor hiccup in the network, you probably don't mind too much if one or two frames get dropped, but you certainly don't want the entire programme to stop while your set-top box requests the missing frame to be re-sent. To get around this, streaming video uses one of the real-time streaming protocols such as RTSP, rather than TCP/IP, and buffers incoming data in its internal memory to cover minor delays.

Even if your home internet connection is fast enough to cope with a high-def stream, that doesn't mean the server will have enough bandwidth to provide it. Each simultaneous user increases the number of gigabytes that must be sent each second by the server. One way around this is to use a peer-to-peer (P2P)

BATTLE OF THE BOXES

There are many set-top boxes to choose from, but what are their main differences?

	BOXEE BOX www.boxee.tv	**APPLE TV 2** www.apple.com/appletv	**ROKU XD** www.roku.com	**VIRGIN TV** www.virginmedia.com
REGION	UK	UK/US	US	UK
PROS	• Facebook and Twitter integration • Plays almost all formats • Automatically sorts your library • High-quality HD upscaling	• Small size • Easy to use • Very stable software • Rent videos and TV shows from the iTunes Store • Stream content from iPod, iPad or iPhone to your TV	• Small size • Open platform allows new channels to be added • Lots of the channels are free • Works with existing subscriptions	• Lots of channels included • Pause live TV with the V+ HD box
CONS	• Hulu support is uncertain • Unusual shape prevents stacking	• Music and photos must be streamed from a PC or Mac • Movies rented on Apple TV can't be transferred to an iPod or iPhone • Limited internet radio support • Lower resolution than Blu-ray	• Most of the channels are US-only	• Requires a cable connection • HD service has a one-off £49.95 activation fee • Requires you to switch phone service to Virgin too
HD?	1080p	720p	1080p	1080i
COST	£199.99 / $325.74	£101 / $164.50	£79.99 / $130.29	Free with subscription package of £6.50 – £25.50/month
THIRD-PARTY SERVICES	Apple movie trailers, Netflix, BBC iPlayer, YouTube, Flickr, Last.fm	Netflix (US-only), YouTube, iTunes, Flickr	Netflix, Hulu Plus, Amazon Instant Video	Sky, Freeview and terrestrial channels, BBC iPlayer
DETAILS	Boxee is actually a software app designed to run on several hardware platforms. The Boxee Box by D-Link is simply the most well-known of the standalone set-top devices that run it. It uses a system of software plug-ins to connect to a wide range of video and audio services and streams. A built-in browser also allows you to connect to any site. The Facebook and Twitter integration means you can show your friends what you are watching and receive recommendations from them.	Unlike the first-generation Apple TV, the newer, smaller second incarnation doesn't have space for a hard disk, so all the content you view must be streamed either from your computer or directly from the internet. Apple TV is mainly designed around access to Apple's iTunes Store and, in the UK, all the movies you access must be rented or bought from there. The only free content that's available to you is what is already on your computer or YouTube videos.	The Roku digital video player began as a device to stream movies from a Netflix account, without using a computer. Later versions have added other channels to stream TV shows. If you already subscribe to a service and Roku has a channel for it, you can watch using your set-top box. There is no extra charge for accessing a channel through the Roku player. Currently there are no UK channels for the Roku, so you can only watch the free channels that don't block non-US connections.	Virgin TV is a competitor with Sky, but instead of delivering content via a satellite dish, it uses a fibre-optic cable connection. Although the technology is very similar to web streaming, you are connected to Virgin's own network instead, not the internet. This means that you can't access other streaming services with the Virgin box. Unlike Sky, pay-per-view movies aren't limited to fixed start times. You select a film from the library and it is streamed directly for you, whenever you want.

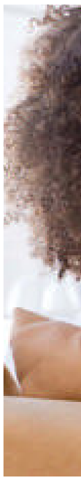
"Set-top boxes run a modified version of an existing computer operating system"

system. This co-opts everyone downloading the stream into helping with the uploading as well. As your set-top box receives network packets, it is simultaneously re-sending them to other users who are slightly behind you. Because the upload bandwidth is separate from the download bandwidth and generally goes unused, this doesn't impact your own viewing experience and the more popular the stream, the more people are uploading and the faster everyone can download.

When the video packets arrive in your living room, they are received by a set-top box. This is effectively a small computer, with a network connection, processor, memory and a graphics chip. Usually though, there is no hard disk. This is because streamed television is discarded as soon as it has been played. If you need to rewind the programme, the set-top box just requests an earlier part of the programme from the server and carries on streaming from there. Set-top boxes run a modified version of an existing computer operating system. The Apple TV uses a version of the iOS found in the iPhone and iPad and the Roku runs Linux, for example. On top of this, there is the client software that handles the decoding of the video stream, the programme controls and the various library and social media features of the set-top box.

Most internet TV services have premium content, that can be served as pay-per-view. To enable this, your set-top box is registered to an account when you sign up for the service. This holds your credit card details, or sometimes a PayPal account at the server end. The set-top box signs in to the server, using its own unique network address to identify itself, and you confirm the purchase using the keyboard or remote control keypad. To prevent your children bankrupting you, or accessing inappropriate content, a PIN or password system can be enabled.

Digital rights management, or DRM, is a technology that restricts your ability to transfer programmes to another device and limits how long you can view them for. It is much less relevant for set-top boxes than desktop computers, because the streamed video isn't stored anyway. But the video streams use DRM to encrypt the data because of the wide array of different devices that could be accessing each service.



Lost Ses
Season finale

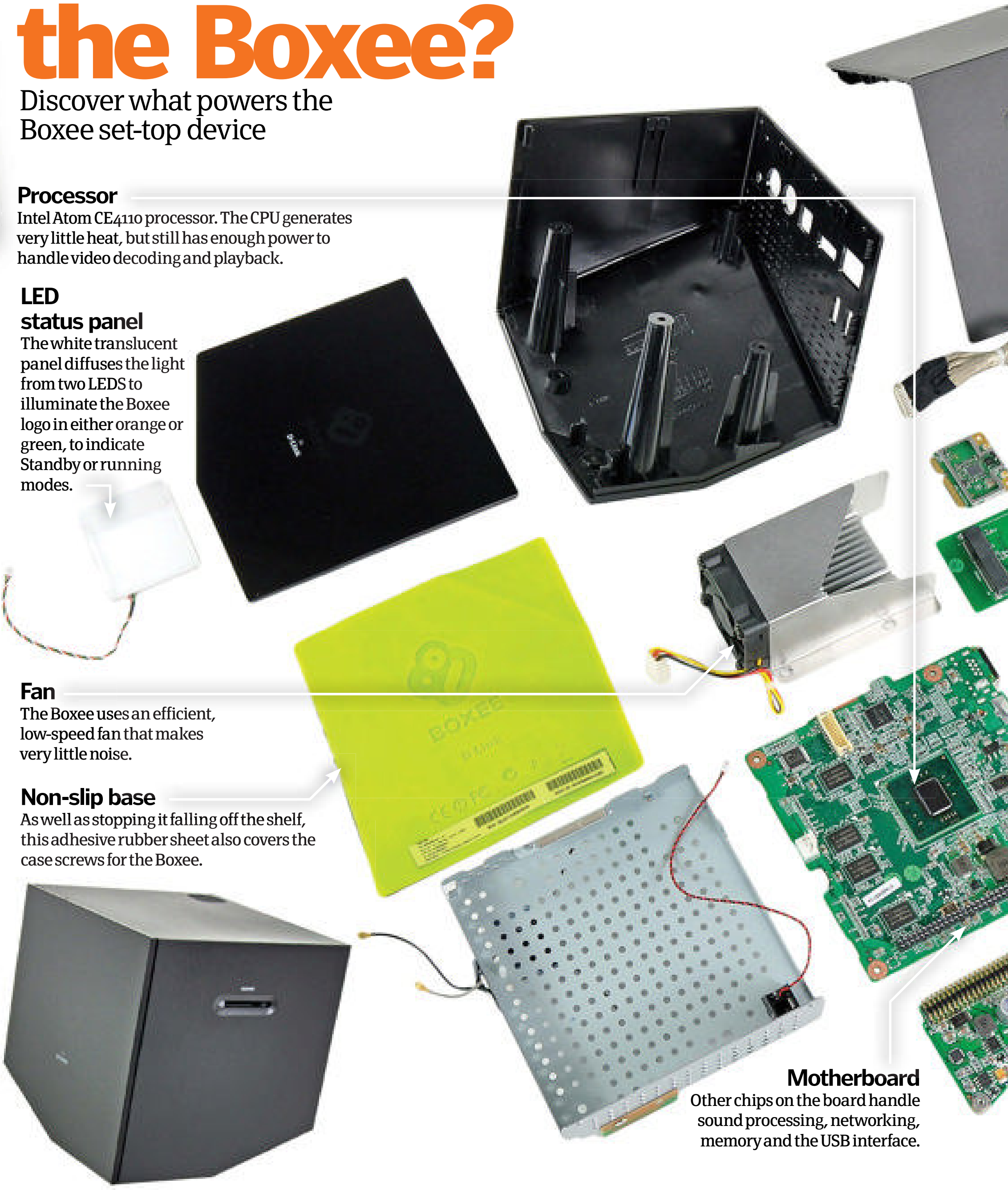
BBC iPlayer

The power behind iPlayer

To put a programme on iPlayer, the BBC starts with the analogue videotape used for broadcast. This is scanned in and digitised, then the file is manually trimmed so that when you press Play, the programme begins on the very first frame. It is then encoded into as many as 15 different formats that are optimised for different playback devices and network speeds. The smallest is a 160kbps format for mobile phones and the largest is 3.2mbps for downloaded HD content. Standard-definition streamed iPlayer video uses 1,500kbps. The files are compressed using the H.264 or VP6 algorithms for iPlayer but these require the Adobe Flash player, so RealPlayer and MPEG-2 are used for devices that can't handle Flash. Programmes are downloaded from two separate server centres, operated by Siemens on behalf of the BBC. Each is designed to back up the other in case of a power outage or hardware failure. Streamed data is distributed more widely, with commercial networks country-wide to provide faster connections. The network continuously balances the load between different servers and can even offload some traffic to servers in Europe to handle the largest peaks, such as the final of *Strictly Come Dancing*.

What's inside the Boxee?

Discover what powers the Boxee set-top device



Processor
Intel Atom CE4110 processor. The CPU generates very little heat, but still has enough power to handle video decoding and playback.

LED status panel
The white translucent panel diffuses the light from two LEDS to illuminate the Boxee logo in either orange or green, to indicate Standby or running modes.

Fan
The Boxee uses an efficient, low-speed fan that makes very little noise.

Non-slip base
As well as stopping it falling off the shelf, this adhesive rubber sheet also covers the case screws for the Boxee.

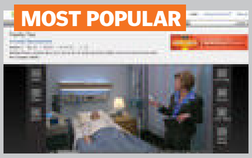
Motherboard
Other chips on the board handle sound processing, networking, memory and the USB interface.

Head to Head
Online TV services

1. iTunes Store
The link with the Apple TV set-top box and the huge rise in video on mobile phones has made the iTunes Store about more than just music.

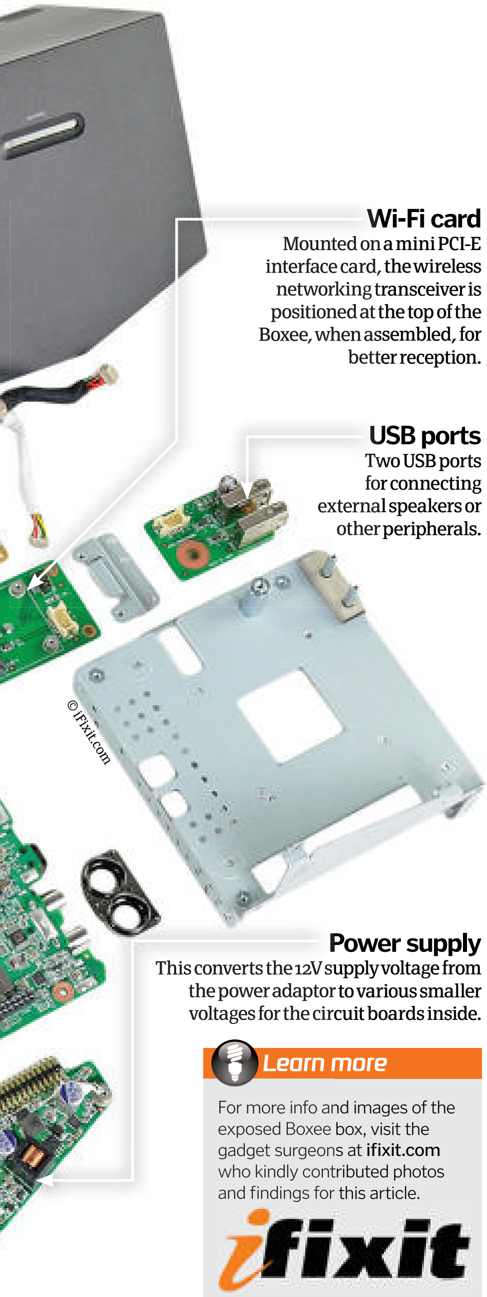
MORE POPULAR

2. BBC iPlayer
With a similar number of programmes to Hulu and higher video quality, it's just the UK-only licence restriction that holds the BBC iPlayer back.



3. Hulu
In the United States, popular online video service Hulu accounts for more video streams than any other internet service apart from YouTube.

DID YOU KNOW? 2.8% of households worldwide will have internet TV by 2012, according to analysis by the Gartner Group



Wi-Fi card
Mounted on a mini PCI-E interface card, the wireless networking transceiver is positioned at the top of the Boxee, when assembled, for better reception.

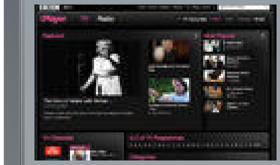
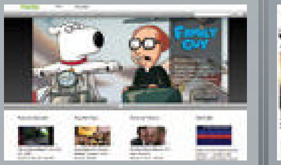
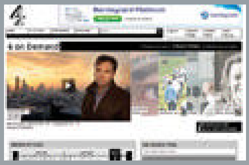
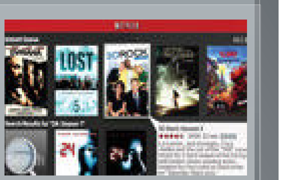
USB ports
Two USB ports for connecting external speakers or other peripherals.

Power supply
This converts the 12V supply voltage from the power adaptor to various smaller voltages for the circuit boards inside.

Learn more
For more info and images of the exposed Boxee box, visit the gadget surgeons at ifixit.com who kindly contributed photos and findings for this article.

CLASH OF THE CLIENTS

Discover the different services on offer from the many software clients available

	BBC iPLAYER www.bbc.co.uk/iplayer	HULU www.hulu.com	4oD www.channel4.com/programmes/4od	NETFLIX www.netflix.com
REGION	UK	US	UK	US
PROS	• Live and 'catch-up' viewing • Available on lots of platforms • Social networking recommendations • Series stacking	• Watch classic and current US TV shows • Widely supported by set-top boxes	• Catch-up programmes for 30 days • Resume where you left off if you are interrupted • PIN system to allow for parental control	• Unlimited streaming service • Tiered video quality to suit connection speed • Many films available on 'first-run'
CONS	• The independently produced programmes are often unavailable • Not available outside UK	• US only • Advert breaks in programmes	• Advert breaks on some programmes • Most American programmes not available	• Subscription fee
HD?	720p	NO	NO	1080p
COST	FREE	FREE	FREE	$7.99/month (approx £5)
DETAILS	 The BBC iPlayer generally allows programmes to be streamed at any time, seven days after broadcast. Some programmes (mainly sports) are offered in simulcast format and can be streamed at the same time as they are broadcast. The Series Stacking feature extends the seven-day limit for some series, so that all the episodes are available until the series has ended. iPlayer streams are available in different resolutions, to suit platforms and connection speeds.	 Hulu works like a US version of iPlayer, except it combines content from major networks such as Fox, NBC, Disney and MTV. Licensing restrictions mean that the service will block anyone attempting to connect from outside the US. As well as networked TV shows, the service has a selection of movies and Hulu will adjust the image quality to match your available streaming bandwidth. The max. resolution is currently only 480p, however, which is approx. equal to DVD quality.	 4oD provides a catch-up service for programmes shown on Channel 4, E4 and More4. Although the shows syndicated from US networks are generally unavailable, there are exceptions, such as *Glee*. The catch-up 'window' is much bigger than iPlayer (30 days instead of seven) and some classic series are available in their entirety, long after they've been broadcast. 4oD does still run some adverts in its streamed programmes, although some stream with none at all.	 Netflix began as an online DVD rental service, but now allows subscribers to stream a limited selection from its rental catalogue via the web to a variety of set-top boxes. This includes both movies and TV shows. The streaming service itself isn't blocked for UK users, but you need a valid US mailing address to sign up for a Netflix account. Netflix has first-run rights to stream many films after the DVD release, but during the window normally reserved for Sky and cable TV.

HOW IT WORKS

DOMESTIC

The technology behind everyday life

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Inside the ultimate hand dryer

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How do these gadgets create hot air in an instant?

84 Yale locks
The famous Yale lock mechanism explained

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What's insde a workman's best friend?

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How to cook your food in the most efficient way

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The technology behind purifying H2O

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The domestic tool that helps you get into your beans

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Understanding how to make beautiful music

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A device that can bring mobility to amputees

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They're all around your house, but what do they do?

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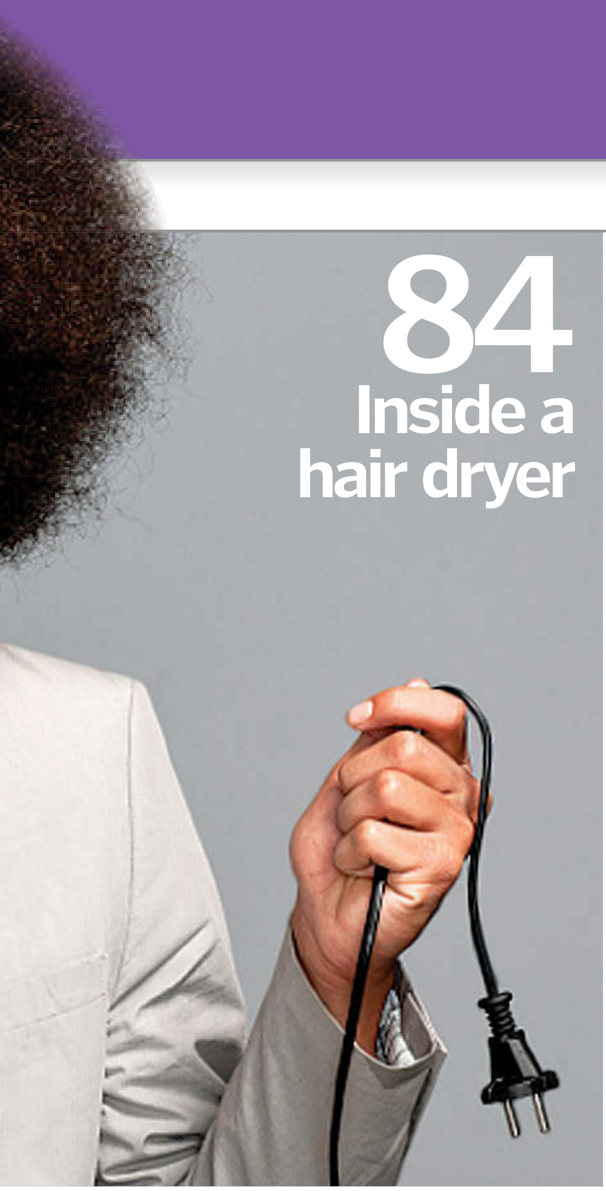

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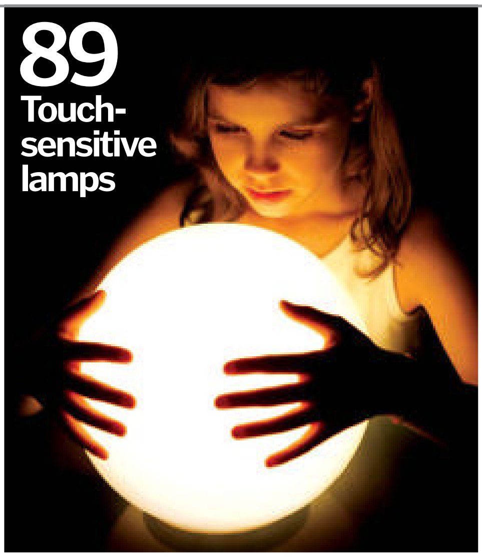

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Conventional warm-air hand dryers never seem to do a great job of actually drying your hands. That's because they simply blow out a low-power stream of warm air that slowly evaporates the water from your hands.

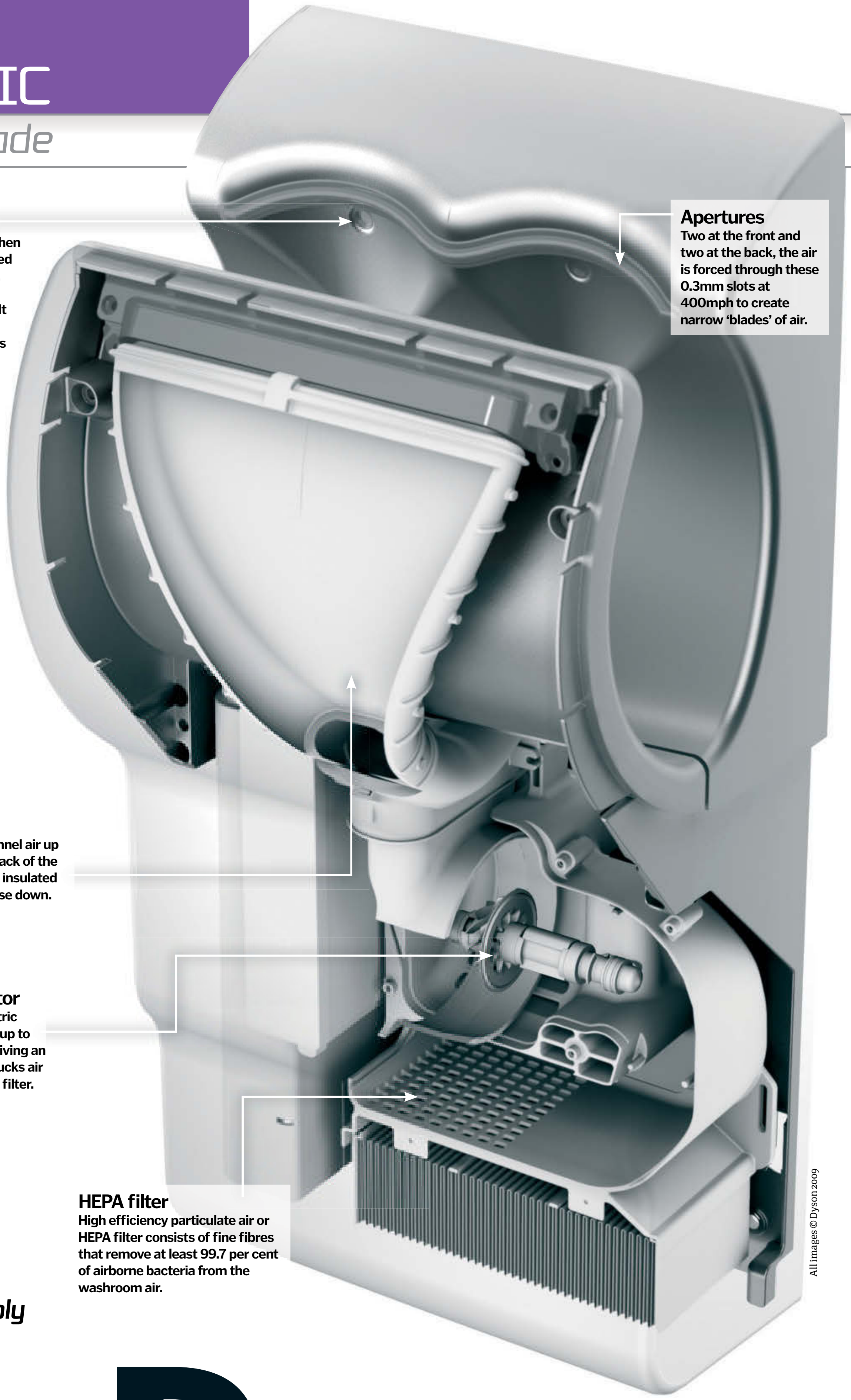
Indeed, inventor Sir James Dyson was so fed up with having to wipe his hands down his trousers after using a dryer, that he took a fresh look at the problem and came up with the Dyson Airblade – a dryer that works much faster, more efficiently and without spreading germs.

To use the Airblade, simply place your hands in it and draw them slowly up. 'Blades' of cool air travelling at 640km/h (400mph) and driven by a special digital motor scrape the water from your hands, leaving them dry. And the Airblade takes just ten seconds to dry your hands, while a conventional dryer takes up to 44 seconds.

What's more, because the air has been effectively filtered as it entered the Airblade, it's free of bacteria, which makes it more hygienic. In fact, the Airblade is said to be the world's only dryer that has been certified as hygienic by NSF International, the public health specialist. Other dryers simply suck in germ-filled air from the washroom, warm it up and blow it back out, germs and all.

Inside the Airblade

The Airblade combines high technology within a remarkably compact and stylish package



Sensors
These sense when hands are placed in the Airblade, turning it on automatically. It then turns off when the hands are removed.

Apertures
Two at the front and two at the back, the air is forced through these 0.3mm slots at 400mph to create narrow 'blades' of air.

Air ducts
Two ducts channel air up the front and back of the dryer. They are insulated to keep the noise down.

Digital motor
High-tech electric motor spins at up to 88,000rpm, driving an impeller that sucks air up through the filter.

HEPA filter
High efficiency particulate air or HEPA filter consists of fine fibres that remove at least 99.7 per cent of airborne bacteria from the washroom air.

All images © Dyson 2009

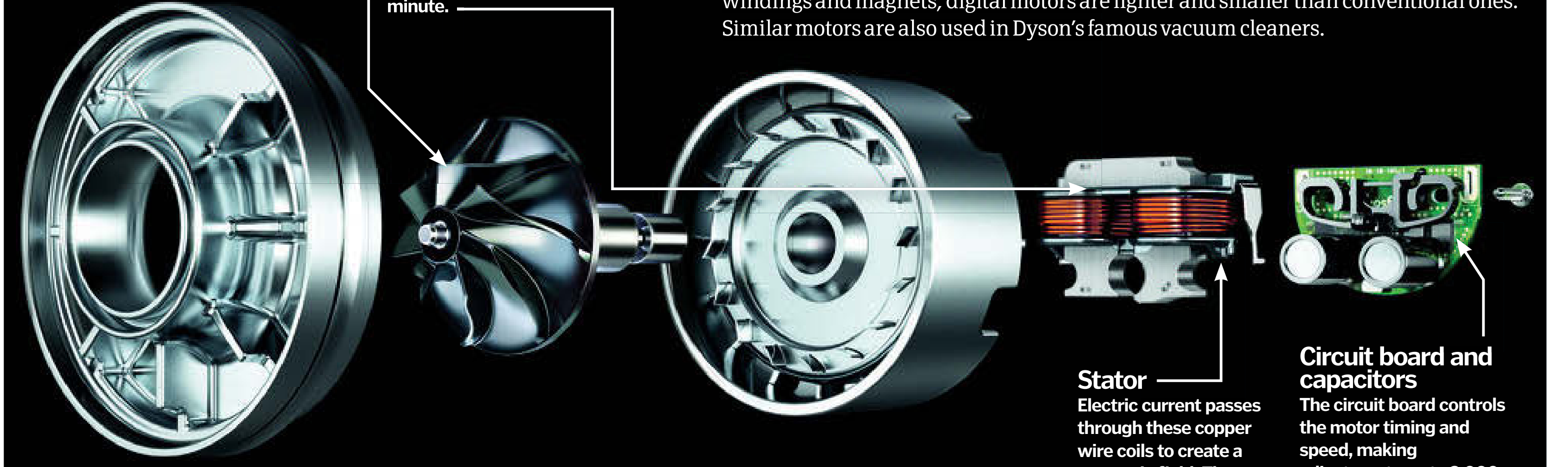
The Dyson

DID YOU KNOW? *The Airblade is accredited by the British Skin Foundation and the Royal Institute of Public Health*

The Dyson digital motor

The secret of the Airblade lies in a special electric motor developed by Dyson's engineers. Conventional electric motors use brushes which create friction, wear out and produce carbon dust. They also have heavy, bulky magnets and windings.

The Dyson digital motor, on the other hand, dispenses with brushes and instead uses digital pulse technology to spin at high speed. Because they don't have such large windings and magnets, digital motors are lighter and smaller than conventional ones. Similar motors are also used in Dyson's famous vacuum cleaners.



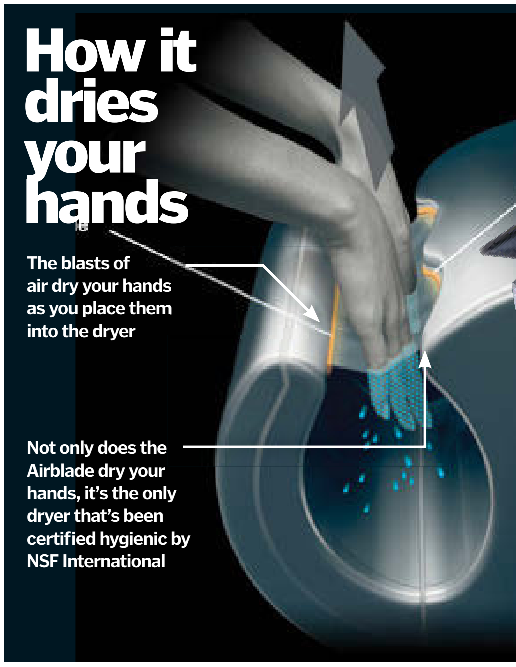
Impeller and vane diffuser
The three-dimensional impeller is designed to suck air in and through the vane diffuser in an efficient manner.

Neodymium magnet
Neodymium is a very strong magnetic material. The rapidly alternating electromagnetic field of the stator causes the magnet to spin at up to 88,000 revolutions per minute.

Stator
Electric current passes through these copper wire coils to create a magnetic field. The polarity of this field switches rapidly from north to south.

Circuit board and capacitors
The circuit board controls the motor timing and speed, making adjustments up to 3,000 times a second. The capacitors supply current to the circuit board.

How it dries your hands



The blasts of air dry your hands as you place them into the dryer

Not only does the Airblade dry your hands, it's the only dryer that's been certified hygienic by NSF International

Impeller factor

The impeller's aerodynamic design means that its continuously curving blades spin at phenomenal speeds. The airflow produced is then channelled up and through the vane diffuser, as well as cooling other components of the system.

5 TOP FACTS THE AIRBLADE

1. **High tolerance** There is just 0.3mm clearance between the impeller and its housing.
2. **Super strong magnet** The neodymium magnet is ten times stronger than a typical everyday magnet.
3. **Super sucker** The Airblade sucks in 37 litres of air every second.
4. **Efficiency dryer** The Airblade uses up to 80 per cent less energy than a conventional dryer.
5. **Cheaper than paper** For the price of one paper towel, the Airblade dries up to 19 pairs of hands.

At last, a hand dryer that doesn't leave you wiping your hands down your trousers!

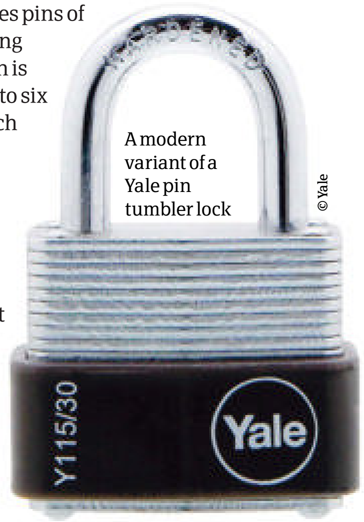
Airblade

> "Only when the correct key is inserted are the pins elevated into alignment"

Yale-style locks

Pin tumbler locks, as made famous by the Yale lock manufacturer, use a simple yet ingenious manner to form a secure locking mechanism that has evolved over thousands of years

A pin tumbler lock is a lock mechanism that uses pins of varying lengths to prevent the lock from opening without the correct key. The pin tumbler design is based on a main barrel that is drilled with five to six cylinder slots that are set close together in a line. Inside each cylinder a metal pin (tumbler) is fitted, with a second pin (driver) on top of it, pushed down by a tiny coil spring. This means that when no key – or indeed the wrong key – is inserted the pins are pushed down across the plug's shear line (the line where the plug is inserted into the outer casing) and it cannot rotate and open. Only when the correct key is inserted are the pins elevated into alignment with the shear line and the lock allowed to open. ✱



A modern variant of a Yale pin tumbler lock

© Yale

DID YOU KNOW? In the Netherlands there is a recreational society dedicated to the art of lockpicking.

5 TOP FACTS
LOCKS

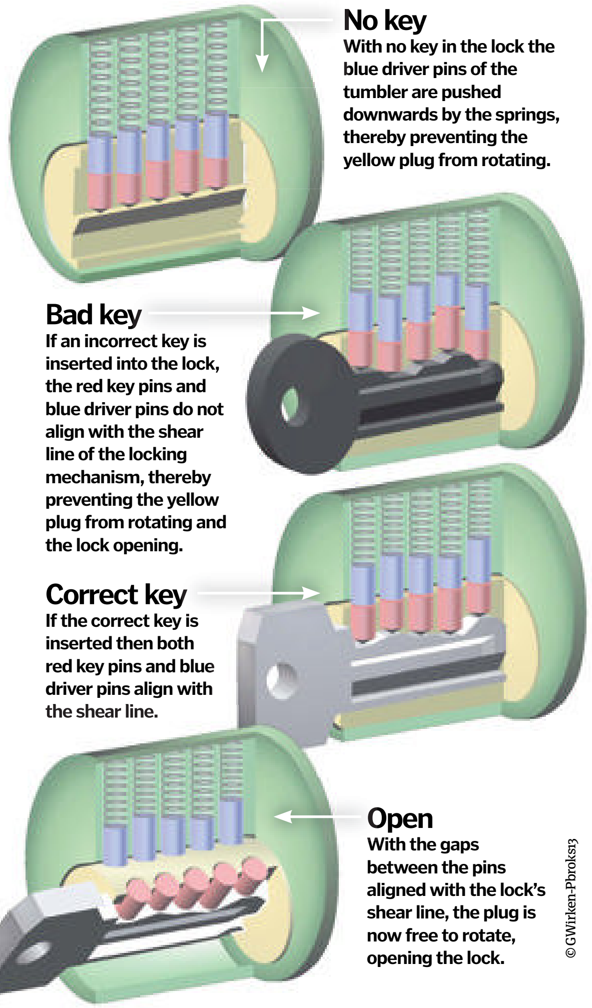
1 Ancient The first pin tumbler locks were used by the ancient Egyptians over 4,000 years ago. However, they were much larger, non-uniform in shape and made of wood.

2 Senior Linus Yale Snr, an American inventor and manufacturer of locks, invented the cylindrical pin tumbler lock in 1848. Linus Yale Snr was one of the founders of the Yale Lock Company.

3 Junior Linus Yale Jnr, the son of Linus Yale Snr, set-up the Yale Lock Manufacturing Company with his father. He specialised in producing locking mechanisms for bank vaults.

4 Vault The primary locking mechanism on many modern bank vaults is a dual-control, time-sensitive combination lock, requiring two people acting in unison to open it.

5 Dining Old bank vaults were often built so secure and from such heavy, impregnable materials, that many still survive today even after the bank is closed. A number are now in use as restaurants.



No key
With no key in the lock the blue driver pins of the tumbler are pushed downwards by the springs, thereby preventing the yellow plug from rotating.

Bad key
If an incorrect key is inserted into the lock, the red key pins and blue driver pins do not align with the shear line of the locking mechanism, thereby preventing the yellow plug from rotating and the lock opening.

Correct key
If the correct key is inserted then both red key pins and blue driver pins align with the shear line.

Open
With the gaps between the pins aligned with the lock's shear line, the plug is now free to rotate, opening the lock.

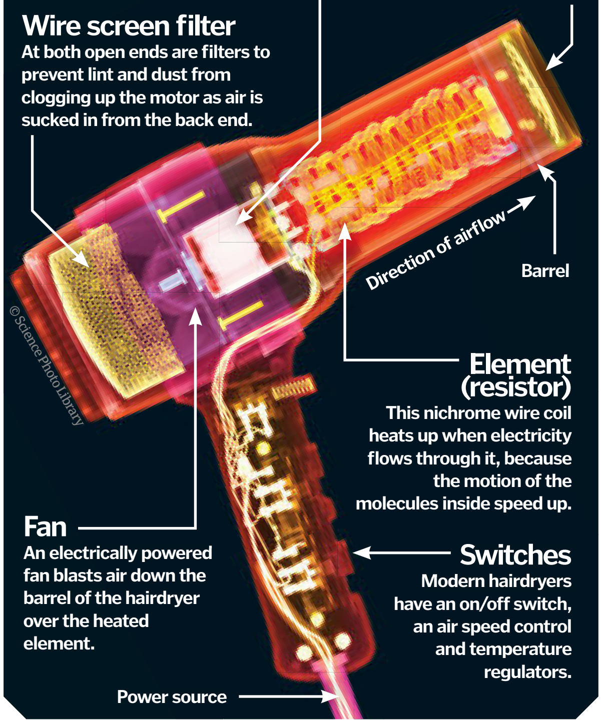
©GWirken-Pbroks13

Be warned: hairdryer results may vary

Hairdryers

How do these domestic appliances create an instant blast of hot air?

The main parts of a hairdryer are a motor-driven fan and an electrically heated element (a very long wire coil with resistance). The element heats up when an electric current flows through it, because electrons bump into the metal atoms in the wire, increasing the vibrations of these atoms. When air from the fan blows through the barrel, the element radiates heat that warms the air up. The hot air passes out through the open end of the dryer (the nozzle), and the user can then direct this hot air onto their hair to speed up the evaporation of water from the surface of the hair. ✱



Fan motor
Electricity enables the electric motor to spin, which powers the fan.

Nozzle
This is the open end through which the hot air escapes.

Wire screen filter
At both open ends are filters to prevent lint and dust from clogging up the motor as air is sucked in from the back end.

Element (resistor)
This nichrome wire coil heats up when electricity flows through it, because the motion of the molecules inside speed up.

Fan
An electrically powered fan blasts air down the barrel of the hairdryer over the heated element.

Switches
Modern hairdryers have an on/off switch, an air speed control and temperature regulators.

©Science Photo Library

5 TOP FACTS
POWER DRILLS

Patent

1 Electrical engineer and Scotsman Arthur James Arnot registered the first patent for an electrically powered drill on 20 August 1889, at the age of just 23.

Duel

2 The first 'pistol-grip' electric drill – which is now the most commonly used – was created and patented by Black & Decker in Maryland, USA, back in 1917.

Primate

3 There is a type of primate called a Drill that is closely related to the baboon. It is Africa's most endangered mammal, with possibly only 3,000 left in the wild.

Primitive

4 The earliest form of drill to be found on Earth is the bow drill, which was primarily used to start fires and not to create holes. It could also be used for woodwork and dentistry.

Rose

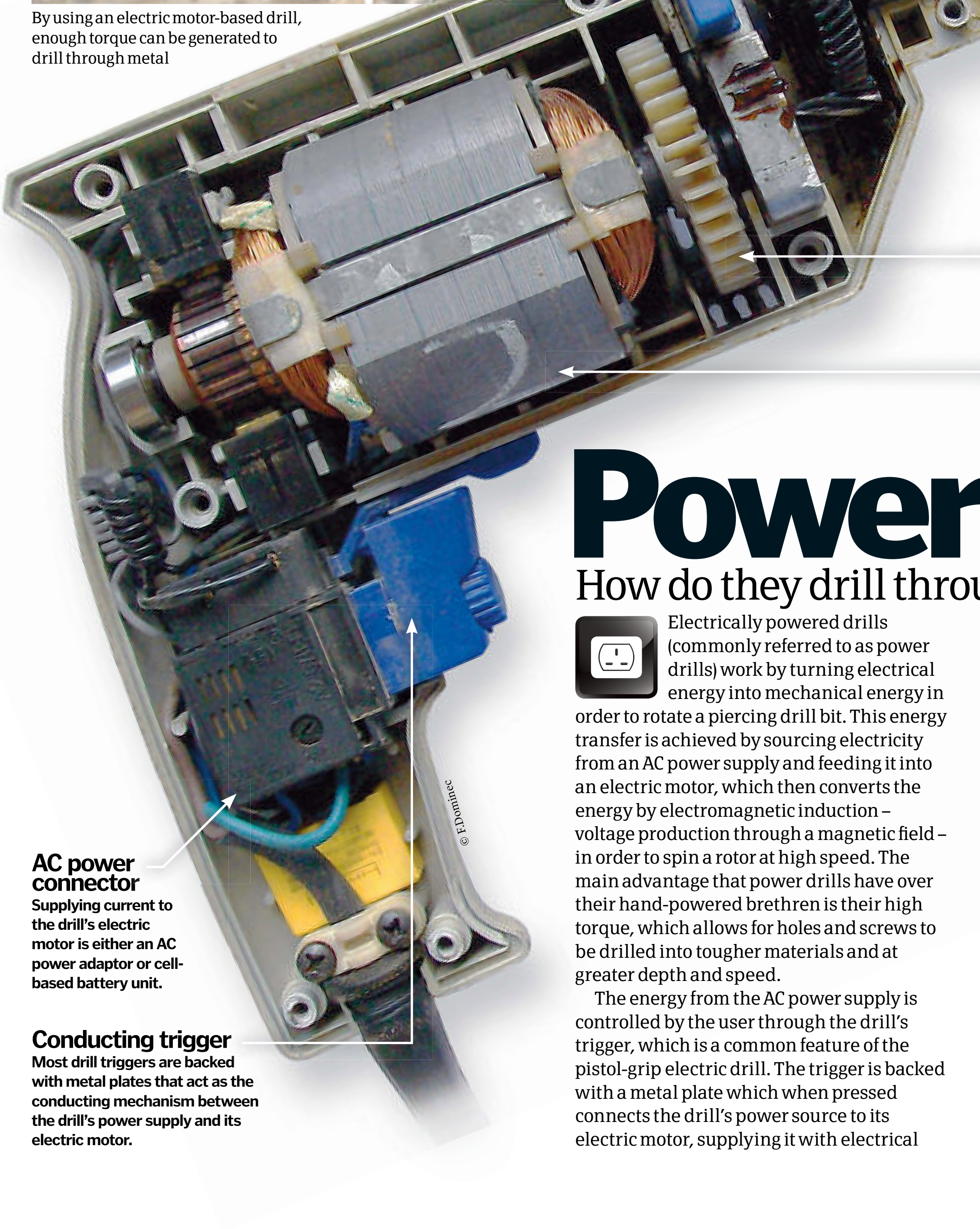
5 Among the many Tudor-era artefacts to be salvaged when the Mary Rose warship was raised from the ocean floor was a selection of wooden drills.

DID YOU KNOW? *The world's largest drill is owned by Russian billionaire Roman Abramovich and is 20m in diameter*

By using an electric motor-based drill, enough torque can be generated to drill through metal

Inside a power drill

The technology behind the tool



© F.Dominec

Drill head/bit
The hole-making part of the system, the drill head makes holes in material by first puncturing its surface and then feeding the threaded drill bit into it under pressure.

Hammer function (not shown)
On some power drills the in-built electric motor not only powers a rotor but also a hammering mechanism, which when used with a specialist drill bit, allows the drill to act as a pneumatic hammer.

Rotor
The circular mechanical cog that is rotated at speed by the electric motor, the drill's rotor rotates the drill head and bit.

Electric motor
The mechanism that converts electrical energy into mechanical energy, the electric motor rotates the drill's rotor by electromagnetic induction.

AC power connector
Supplying current to the drill's electric motor is either an AC power adaptor or cell-based battery unit.

Conducting trigger
Most drill triggers are backed with metal plates that act as the conducting mechanism between the drill's power supply and its electric motor.

Power drills

How do they drill through metal?

Electrically powered drills (commonly referred to as power drills) work by turning electrical energy into mechanical energy in order to rotate a piercing drill bit. This energy transfer is achieved by sourcing electricity from an AC power supply and feeding it into an electric motor, which then converts the energy by electromagnetic induction – voltage production through a magnetic field – in order to spin a rotor at high speed. The main advantage that power drills have over their hand-powered brethren is their high torque, which allows for holes and screws to be drilled into tougher materials and at greater depth and speed.

The energy from the AC power supply is controlled by the user through the drill's trigger, which is a common feature of the pistol-grip electric drill. The trigger is backed with a metal plate which when pressed connects the drill's power source to its electric motor, supplying it with electrical energy to be converted into the mechanical energy that is necessary to rotate the drill bit. Modern drills employ multi-staged triggers, allowing pressure-sensitive control of the rotational speed dependent on how much electricity is directed to the drill's electric motor.

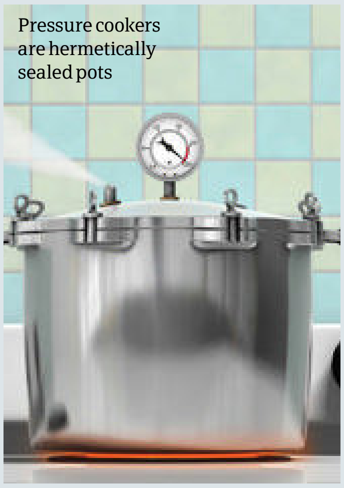
Construction apprenticeships start young these days

> "The pressure within the pan increases massively"

Pressure cookers

How do they cook food so quickly?

Pressure cookers work by raising their internal temperature above a saucepan's capabilities. They achieve this by hermetically sealing their internal structure through a lid/gasket clamping system that restricts the escape of steam and liquids below a pre-set temperature. Through this the pressure within the pan increases massively and allows the internal liquid to rise to a higher temperature before boiling, thereby cooking any foodstuffs faster. Maximum pressure is controlled by a regulator fitted into the lid, which only releases steam when it reaches its pre-set pressure level. In case the regulator gets blocked, a safety valve is also fitted into the lid, which will open if pressure levels increase beyond the regulator's maximum.

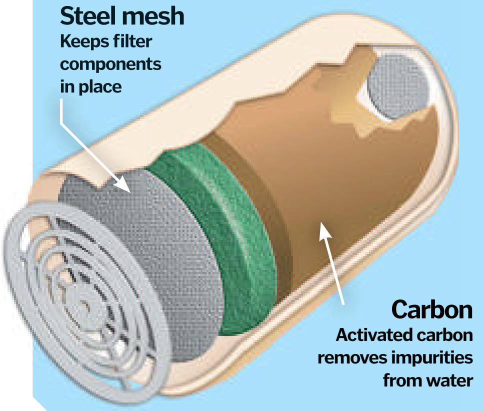

Pressure cookers are hermetically sealed pots

Water filters

Removing impurities from water

There are multiple types of water filters, which through physical, chemical and biological processes work by removing impure substances from water. The most common type of filtration system is that which uses granular-activated carbon, usually in the form of charcoal sheets. The charcoal is treated with an oxidisation process that opens up millions of tiny pores between its carbon atoms, increasing – due to its large porous surface – its ability to absorb (chemically bond with) particulate matter from the water. Once the carbon sheet is saturated with impurities, it's then cleaned by heating it in a furnace. Carbon-based systems are commonly found in household water filters.

Another method used mainly in laboratory or industrial settings where macromolecular solutions need to be purified is ultrafiltration. This works by generating hydrostatic pressure to force liquid against a semi-permeable membrane. Solids and solutes of high molecular weight (ie, larger than a water molecule) are caught by the system's membrane, while water and low molecular weight solutes pass through into the collection area. This allows the geometry of the membrane to be varied according to local conditions and severity of impurities.


Steel mesh
Keeps filter components in place

Carbon
Activated carbon removes impurities from water

The filter removes impurities from water

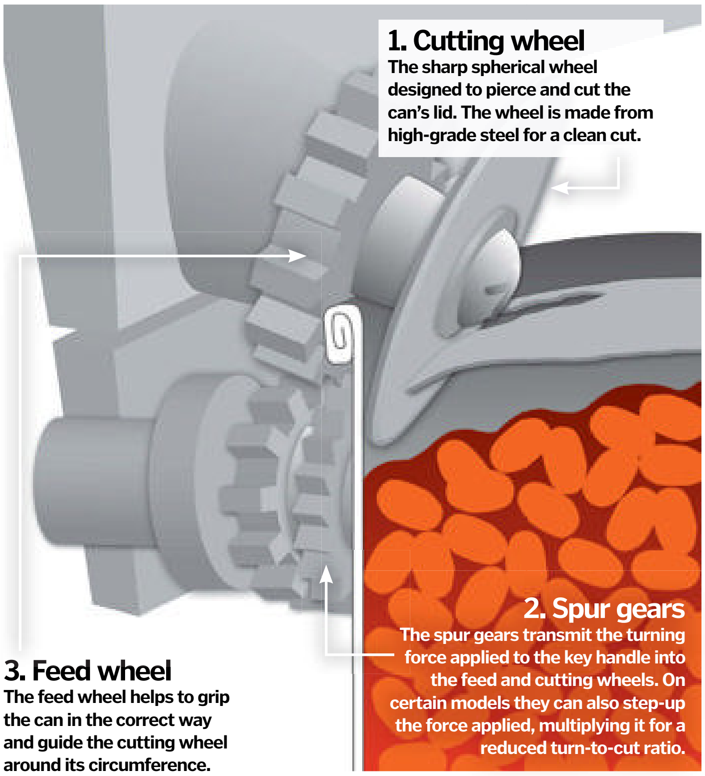
Desperate times call for desperate measures

Can openers

The easy-to-use can-cutting kitchen device explained

Rotating wheel, plier-grip can openers work by transferring the rotational movement of their key handle – which is rotated by the user – into a circular cutting wheel in order to pierce and cut the lid. To do this the opener uses a system of three gears: two spur gears to transmit the rotational motion of the key to the cutting wheel – which can also step-up the force applied – and one feed gear to guide its cutting path round the rim.

In order to further stabilise the grip of the can between the feed gear and the cutting gear, the plier-type handle also allows the user to transfer tension to the cutting plane. The cutting wheel tends to be made from high-grade steel capable of breaking the resistance threshold of the softer lid material and is manufactured with sharp, tapered edges for a clean cut.


1. Cutting wheel
The sharp spherical wheel designed to pierce and cut the can's lid. The wheel is made from high-grade steel for a clean cut.

2. Spur gears
The spur gears transmit the turning force applied to the key handle into the feed and cutting wheels. On certain models they can also step-up the force applied, multiplying it for a reduced turn-to-cut ratio.

3. Feed wheel
The feed wheel helps to grip the can in the correct way and guide the cutting wheel around its circumference.

5 TOP FACTS PIANOS

Harp

1 Inventor Bartolomeo Cristofori, named his invention the gravecembalo col piano e forte, translated from Italian to English to mean 'harpsichord with soft and loud'.

Tense

2 By the late-19th Century piano string tension had been determined at 16 tons, however due to developments in the 20th Century, 30 tons is now possible.

Super-grand

3 The largest piano to buy is the Fazioli F308, a grand piano over 3.08m. A fourth pedal brings the hammers closer to the strings, decreasing volume while maintaining tone.

Spruce

4 High-quality pianos use quarter-sawn, defect-free spruce boards to make their soundboards. The spruce is dried over time for the best vibration and energy transfer.

Chamber

5 The piano was wildly popular in the 18th Century, spurred by musicians such as Mozart and Clementi. It became the instrument of choice for chamber music and concerts.

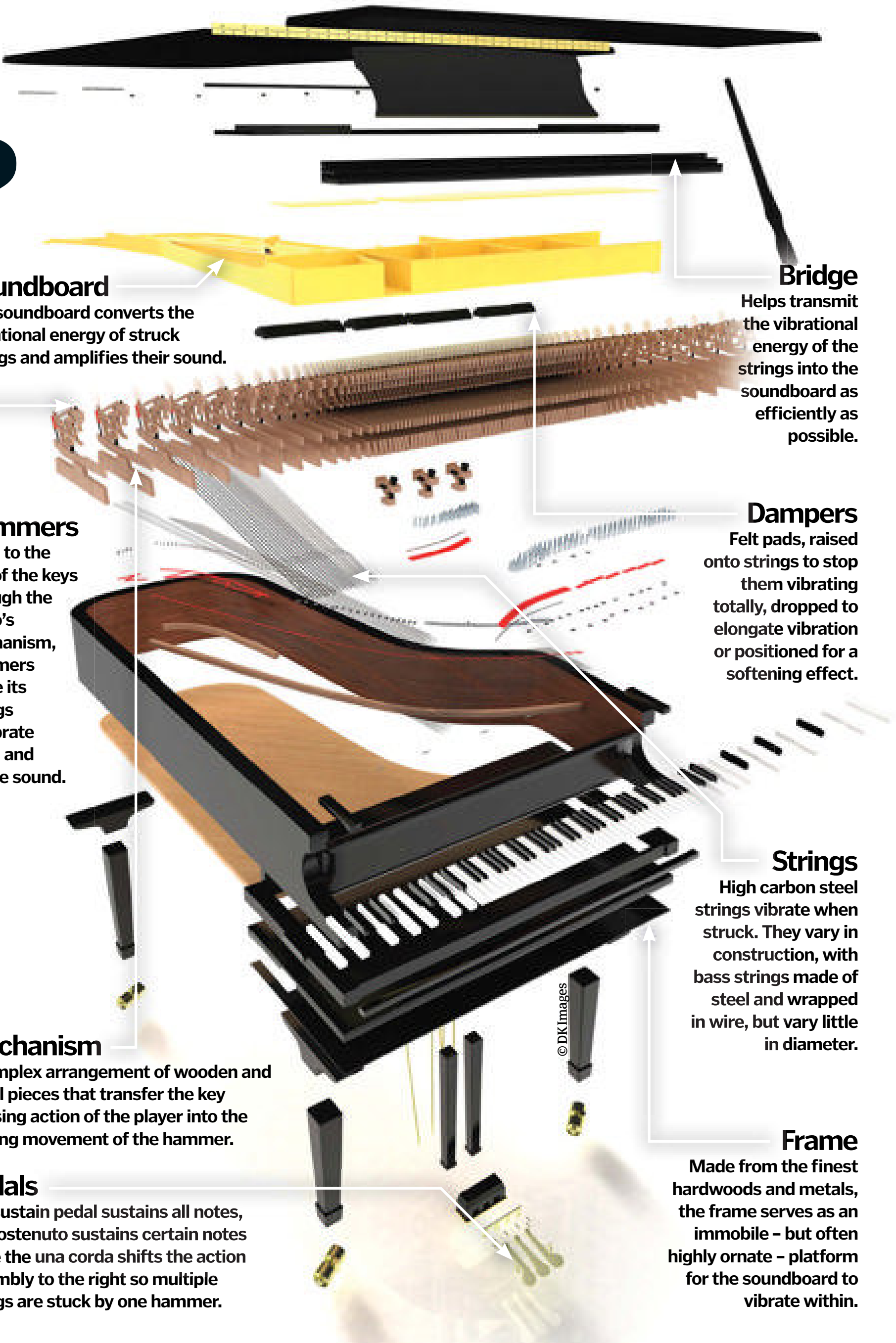
DID YOU KNOW? *The invention of the piano is credited to Bartolomeo Cristofori in 1709*

How does a piano work?

What goes on inside one of the most popular musical instruments on the planet?

Pianos work by transmitting the vibrational energy of taught wire strings into a soundboard, which in turn converts the vibrational energy into sound. The piano achieves this through both its construction materials and action mechanisms. Pianos consist of five main parts: the frame, soundboard, strings, hammers and keys. The frame is constructed from metal and serves as a stable, immobile platform from which its strings (metal wires) and soundboard (vibration to sound conversion mechanism) can vibrate efficiently. Steel is used as it helps mitigate unwanted vibrational energy being transmitted to the rest of the piano and surrounding area, a problem that leads to distortion of produced sounds. The hammers act as a striking mechanism, and when the piano's keys are pressed by the player, they rise to strike their corresponding strings in order to produce vibrational energy.

The physics of the piano work in a chain-reaction. When a key on the keyboard is pressed, a complex system of jacks, pivots and levers raise a suspended hammer upwards to strike an overhung string, as well as a string damper (a felt block) that, once the string is stuck, comes into contact with the string and ceases its vibration. In the short time between the hammer striking the wire and damper ceasing its motion, the vibrational energy is carried down the string and over a 'bridge', a raised bridge-shaped structure over which the string is tightly stretched. The bridge receives this vibrational energy and transfers it into the piano's soundboard, a wooden board chosen for its resonant properties that through the principle of forced vibration vibrate at exactly the same frequency of the struck string. Consequently, due to the large, expansive size of the board, the quiet tone created by the string is increased, and produces a loud note.



Soundboard
The soundboard converts the vibrational energy of struck strings and amplifies their sound.

Bridge
Helps transmit the vibrational energy of the strings into the soundboard as efficiently as possible.

Hammers
Fixed to the end of the keys through the piano's mechanism, hammers strike its strings to vibrate them and create sound.

Dampers
Felt pads, raised onto strings to stop them vibrating totally, dropped to elongate vibration or positioned for a softening effect.

Strings
High carbon steel strings vibrate when struck. They vary in construction, with bass strings made of steel and wrapped in wire, but vary little in diameter.

Mechanism
A complex arrangement of wooden and metal pieces that transfer the key pressing action of the player into the striking movement of the hammer.

Frame
Made from the finest hardwoods and metals, the frame serves as an immobile – but often highly ornate – platform for the soundboard to vibrate within.

Pedals
The sustain pedal sustains all notes, the sostenuto sustains certain notes while the una corda shifts the action assembly to the right so multiple strings are stuck by one hammer.

© DKImages

© Gryffindor

A classic example of a grand piano, fitted with soft, muffler and damper pedals

The three standard pedals of a grand piano: una corda, sostenuto and sustain

Flex-Foot Cheetah

How does this artificial limb help disabled athletes compete?

The Flex-Foot Cheetah works by storing and releasing energy within a carbon fibre sprinting foot, a prosthetic that mimics the reaction of the anatomical foot/ankle joint to allow amputees to run quickly and naturally. The foot is J-shaped and resembles the hindquarter of a cheetah, acting like a spring and shock absorber combined. As the unit is compressed on impact, energy is stored and stress absorbed within it – which would otherwise be transferred directly to the user's knee, hip and lower back – before being released into the ground at toe-off to propel the user forward.

The foot's design is revolutionary, with areas of high stress – such as the apex of the J-curve – fitted with more layers of carbon fibre, while areas in need of greater flexibility are fitted with less, allowing for a dynamism that would not be possible with a single-sized material. Further, due to the fact that the Flex-Foot Cheetah has no heel, the wearer is constantly positioned on the balls of their feet, accurately mimicking how an able-bodied runner sprints. Importantly, however, while the system is refined and has allowed amputees to rack up many world records, due to its passive nature – the foot has no motors, sensors or microprocessors – the Cheetah only returns 80 per cent of the energy stored during compression, a far way off the 249 per cent of a normal, able-bodied foot/ankle/gastroc system.

> "As the unit is compressed on impact, energy is stored and stress absorbed within it"

5 TOP FACTS PARALYMPICS

1 Wartime
The first Paralympics was held in 1948 at the same time as the Summer Olympics in London, United Kingdom. Initially, only a small band of British World War II veterans took part.

2 Diamond
The current 400m world record is held by South African Oscar Pistorius, who clocked a rapid 47.04 seconds in 2010, beating his earlier 2008 gold medal winning time of 47.49.

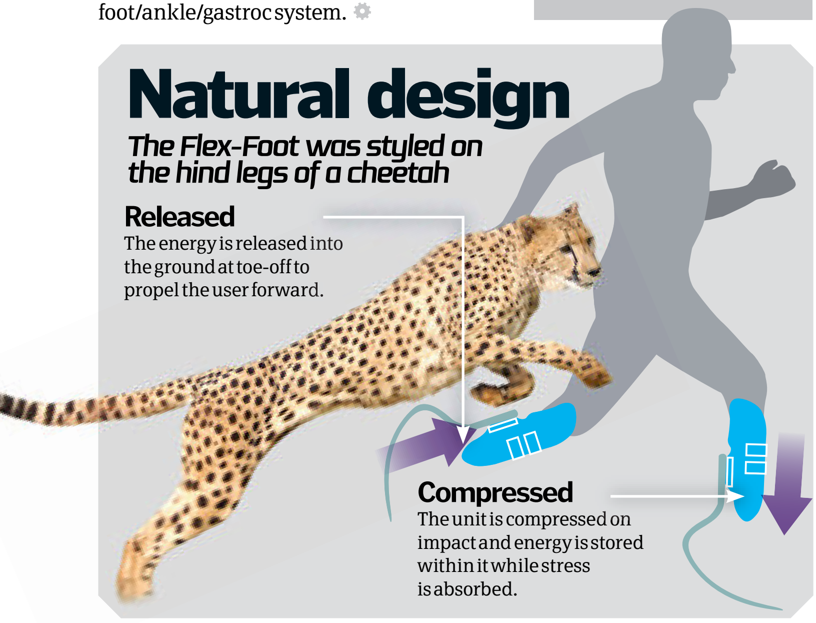
3 Wonderland
The first Winter Paralympics was held in Sweden in 1976. They were the first Games to feature athletes other than those wheelchair-bound. Now the games allow competitors with a broad array of disabilities to take part.

4 Scandal
The Paralympic Games has been subjected to numerous cheating scandals since it was launched. Competitors have been found guilty of steroid use, autonomic dysreflexia and actually being able-bodied.

5 Champion
Paralympian Trischa Zorn is the most decorated competitior in the history of the Games. From 1980 to 2004 she won a total of 55 medals, 41 of which are gold, in blind swimming events.

Natural design

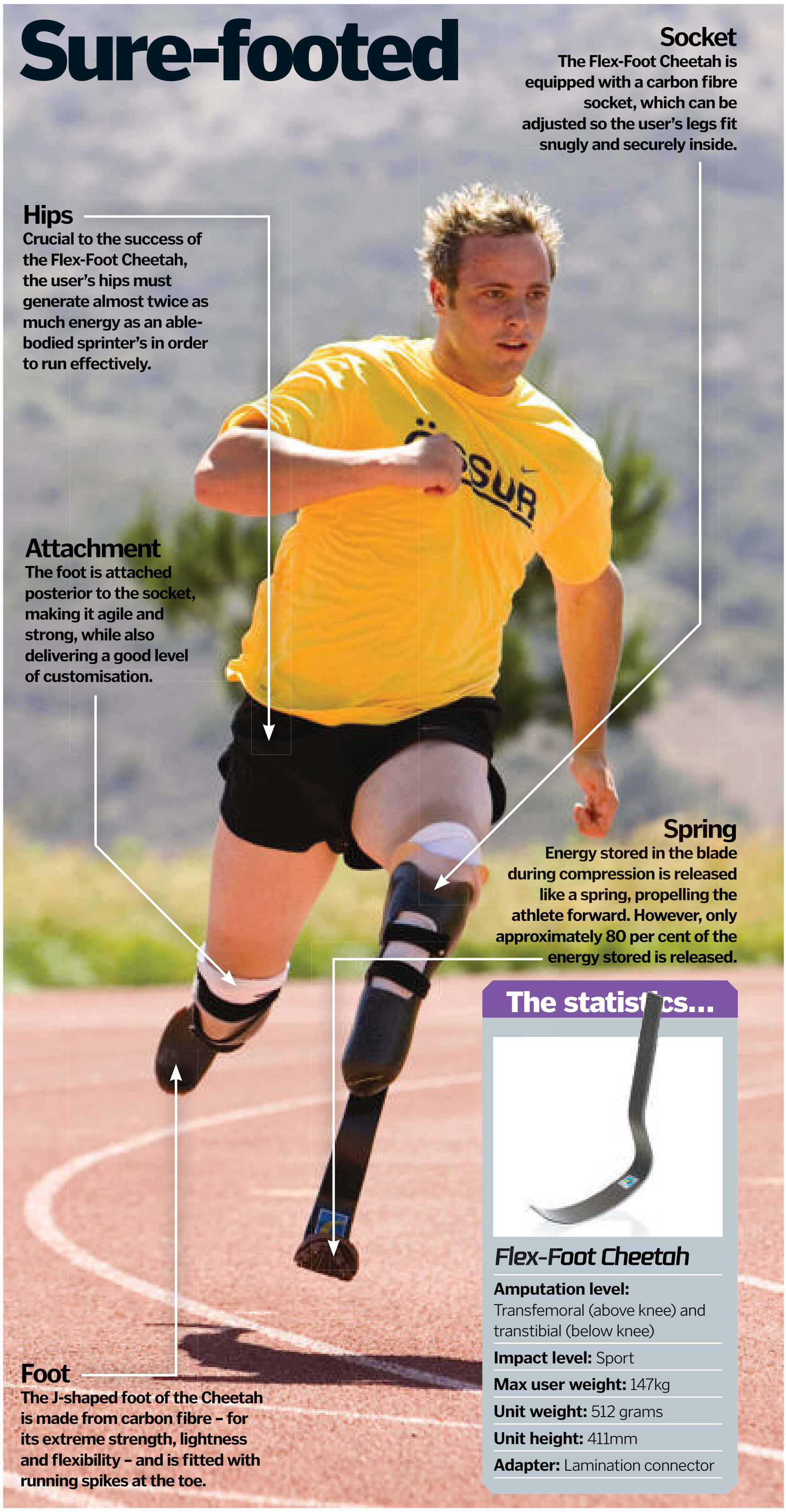
The Flex-Foot was styled on the hind legs of a cheetah



Released
The energy is released into the ground at toe-off to propel the user forward.

Compressed
The unit is compressed on impact and energy is stored within it while stress is absorbed.

Sure-footed



Socket
The Flex-Foot Cheetah is equipped with a carbon fibre socket, which can be adjusted so the user's legs fit snugly and securely inside.

Hips
Crucial to the success of the Flex-Foot Cheetah, the user's hips must generate almost twice as much energy as an able-bodied sprinter's in order to run effectively.

Attachment
The foot is attached posterior to the socket, making it agile and strong, while also delivering a good level of customisation.

Spring
Energy stored in the blade during compression is released like a spring, propelling the athlete forward. However, only approximately 80 per cent of the energy stored is released.

Foot
The J-shaped foot of the Cheetah is made from carbon fibre – for its extreme strength, lightness and flexibility – and is fitted with running spikes at the toe.

The statistics...

Flex-Foot Cheetah

Amputation level: Transfemoral (above knee) and transtibial (below knee)

Impact level: Sport

Max user weight: 147kg

Unit weight: 512 grams

Unit height: 411mm

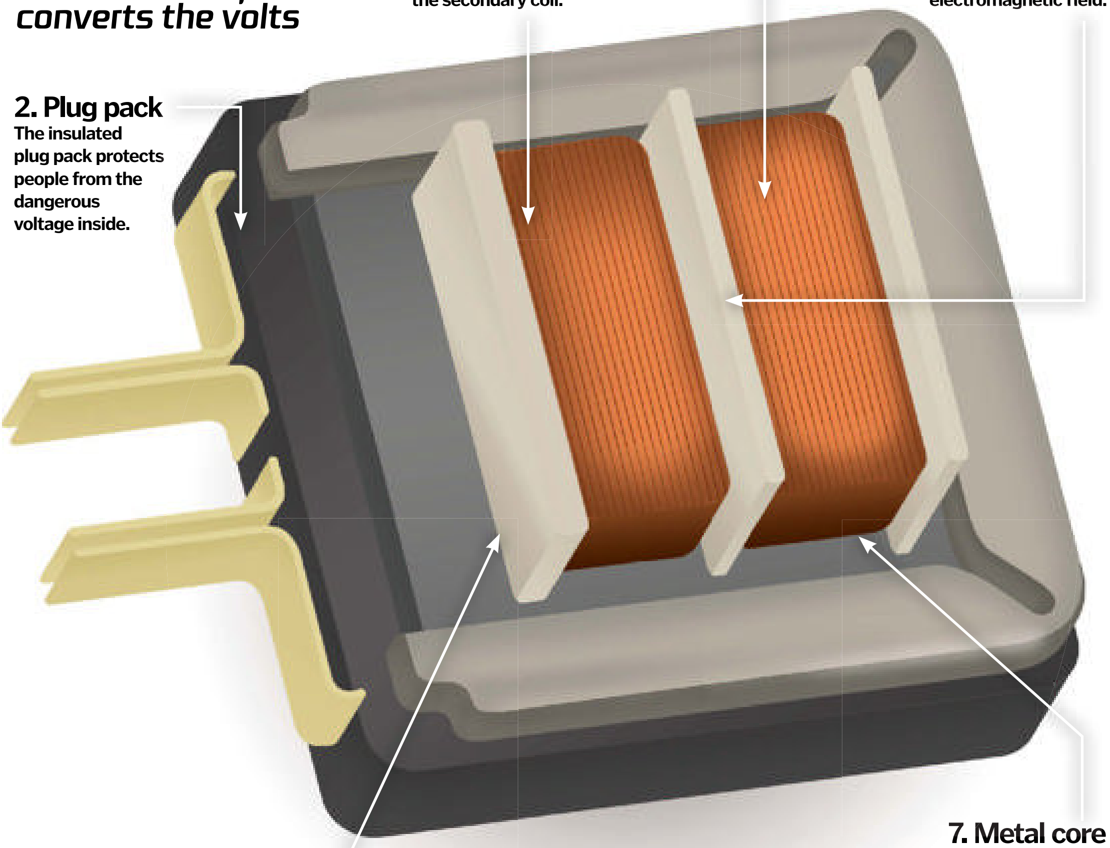
Adapter: Lamination connector

X2 images © Ossur

DID YOU KNOW? *Touch-sensitive lamps that change brightness per touch work by rapidly switching the bulb on and off*

Inside a powercube

How the transformer converts the volts



1. Plastic bobbin
The plastic bobbin secures the coils in place and ensures they remain separated from each other.

2. Plug pack
The insulated plug pack protects people from the dangerous voltage inside.

3. Coiled wire
Concentrically wrapped, each wire is insulated from each other so the current follows the longest path, creating a larger electromagnetic field.

4. Primary coil
The primary coil receives 110-240 volts of alternating current (AC). It will consist of many more turns than the secondary coil.

5. Secondary coil
With fewer turns, the secondary coil outputs a current with a lower voltage than the original input.

6. Diodes (not shown)
Two diodes convert the output of the secondary coil into direct current (DC). Diodes only allow electric current to flow in one direction.

7. Metal core
The metal core increases the primary coil's electromagnetic field and acts as a magnetic pathway to the secondary coil.

How powercube transformers work

How 240 volts is converted into a safe power supply for home gadgets

Look around your home and you will probably find several transformers connected to laptops, charging phones and powering alarm clocks. Transformers convert relatively high domestic voltages into lower voltages suitable for home appliances.

Inside is a single core of metal. Wrapped around it are two separate coils of wire – a primary coil and a secondary coil. The primary coil receives the 110-240 volt mains alternating current (AC) power supply. This generates an electromagnetic field. An electromagnetic field will always generate an electric current in a wire within its proximity – a process called electromagnetic induction.

The primary coil's electromagnetic field induces an electric current of a lower voltage in the secondary coil. How much lower depends on the ratio of turns between each coil. If the primary coil had 1,000 turns and the secondary coil had 500 turns, the output voltage would be halved. Finally, two diodes convert the output into direct current (DC) for use in home appliances.

Here's one that we broke earlier!

How do touch-sensitive lamps work?

How your body's own conductivity can light up a room

Everything, including people, has a certain level of capacitance; the ability to retain an electrical charge. In standby mode, the lamp's circuitry sends a weak electrical current to its external metal layer until its capacitance is full. This flow of current remains a constant value until a person touches the metal surface. The human body can conduct electricity quite well so electrons freely flow from the lamp's surface into his or her body.

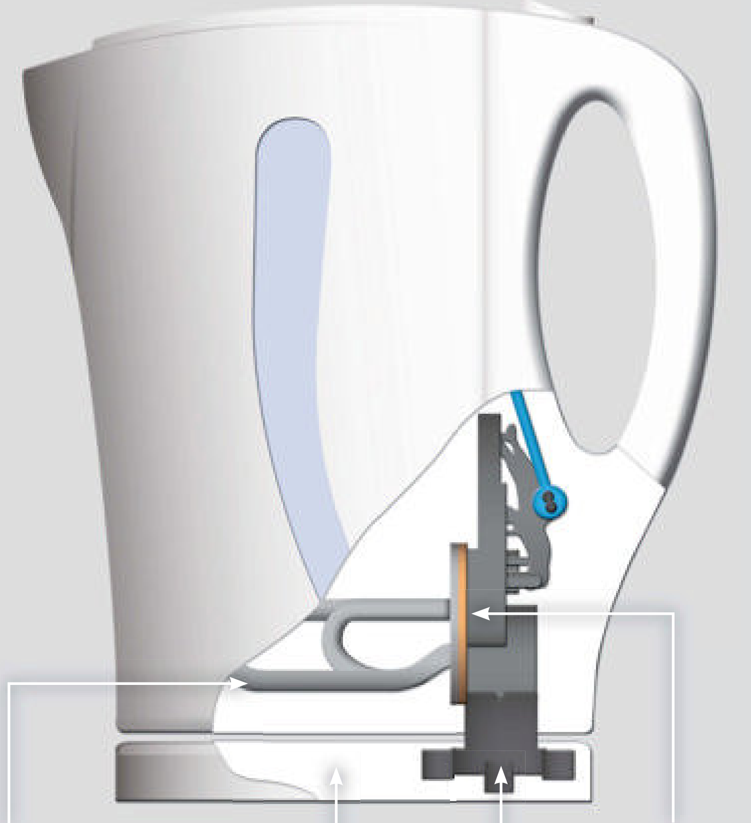
As a result, the capacitance is increased and a higher current is required to electrify both the lamp and the person. A circuit detects the increase in current and sends a signal to a 'binary flip flop' switch. This 'flips' its output signal between off and on each time the lamp is tapped, switching the bulb off and on. The 'flip flop' switch 'remembers' the last status of the bulb so it can react accordingly after each touch.

Electric kettles explained

Made possible by design breakthroughs in the Twenties and Thirties, the electric kettle makes tea-making a piece of cake

The electric kettle works thanks to two key design breakthroughs achieved in Britain in the Twenties and Thirties. The first is the immersed heating resistor, the piece of technology responsible for actually raising the temperature of the water in the kettle. Resistors, which take the form of the heating element in the bottom of the kettle, work by resisting the flow of electric current passed through them. This creates resistance and consequently heat. This heat is then passed into the water, which is then subsequently heated up. The second of these advances allowed for an automatic cut-off point, preventing the kettle from perpetually heating up the water. A bimetallic strip was introduced to the electric kettle by Russell Hobbs in 1955, which, when heated by steam expanded, triggering a shut-off switch.

Although some kettles have fancier and more complex heating and shut-off designs, it is through these two basic principles that the electric kettle evolved into the appliance we have in our kitchens and workplaces today.



Heating element
This works by resisting the flow of electrical current, which creates the heat the heats the water.

Detachable base
A feature on all modern kettles, the base contains contacts that allow the flow of electricity to the element.

Power adapter
Connecting the heating element to the power supply allowing the flow of current through the element.

Bimetallic strip
When the water heats up it causes the bimetallic strip to bend which triggers the switch that cuts off the power.

Do eco bulbs save energy?

Creating light that doesn't cost the Earth is 'exciting' stuff – literally

Light is a complicated thing. It can behave like a wave or a particle. Most theories in physics talk about it behaving like a wave, when it travels fast splits into the colours of the rainbow and combines again to make white, and creates beams (think of the sunbeams you see through a window). Light bulbs however, whether energy-saving or traditional, rely on light's particle-behaviour alter-ego.

In 1905 Albert Einstein studied how light can possibly generate energy. This is called the photoelectric effect. He theorised that light can create particle-like entities called photons, which throw off energy. It's possible to create light-emitting photons under the right conditions, and light bulbs take advantage of this.

The traditional light bulb had been invented a good 28 years before Einstein's theory, and utilised a variant on it. An atom of a reactive element – tungsten is usually the flavour of choice thanks to its capability to withstand intense heat – will produce light when the electrons within it are excited by an external force. This makes them temporarily speed up and widen their orbit around the nucleus in the middle of an atom. When they're pulled back to their original orbit, they throw off a photon. Traditional light bulbs use heat passing across a filament of tungsten to do this. Energy-saving light bulbs use a tube filled with argon gas and mercury vapour. When electrons move from one end to the other, they cause the mercury atoms in the tube to throw off light in the ultraviolet range.

Producing heat requires much more energy than creating enough charge to excite the mercury atoms inside a fluorescent tube. This means that energy-saving light bulbs are exactly that: they require less energy to be pumped into them in order to function. And as they don't heat up the element that creates the light, it also lasts longer, giving them a longer life span.

DID YOU KNOW?

In a fluorescent tube visible light is produced as a secondary effect of the mercury vapour throwing off photons. The ultraviolet photons react with the phosphor coating inside the tube to produce visible light.

5 TOP FACTS
FIRE EXTINGUISHERS

Remove basic elements
1 All fire extinguishers work by removing any one of the three basic elements necessary for fire to burn – these being oxygen, heat and fuel.

Type matters
2 There are eight different types of fire extinguisher available, including: water and foam, dry and wet chemical, clean agent and powder variants.

Class of fire
3 The five classes of fire are class a, ordinary combustibles; class b, flammable liquids; class c, electrical; class d, combustible metals and finally class k, oil fires.

Fire in the hole
4 The fire grenade was an early experiment involving a small glass bottle filled with extinguishing agent thrown into fires in an attempt to put them out.

Colour co-ordinated
5 The colour of a fire extinguisher varies from country to country. UK fire extinguishers are red with coloured bands to denote their type.

DID YOU KNOW? *The very first fire extinguisher was patented in England in 1723*

Inside fire a extinguisher

Since their creation in the 18th Century, fire extinguishers have played their part in saving countless lives

Another family barbecue suffers due to over-enthusiastic use of firelighters

There are two main types of fire extinguisher: those with internal stored pressure, and those where pressure is delivered through a cartridge system. The most common by far of these two is the former, with cartridge-based systems reserved mainly for industrial use. Both variants of extinguisher work in the same way though, removing one of the three things fire needs to burn: oxygen, heat or fuel. This is achieved by holding their contents under pressure – either from pressure within the main tank or from the external cartridges – causing a rapid expulsion of extinguishing agent when operated. Basically, when the lever is squeezed on the top of the canister, a valve is forced open allowing the release of the pressurised gas and contained agent through the fire extinguisher's nozzle.

Despite the delivery method and vehicle split between only two main variants, there are many differing extinguishing agents used in modern-day fire extinguishers. Water and water-additive fire extinguishers work by propelling water by pressurised gas onto a fire to cool it and soak its fuel, preventing it burning further. Foam and powder extinguishers – which propel powder and foam under low pressure – do not put out fires in this manner, achieving a neutral environment by smothering a fire with its agent, cutting off its oxygen supply instead of dowsing its fuel. CO2-based systems work in a similar manner too, expelling the gas – which is extremely cold – onto the blaze, cooling it and displacing any oxygen in the atmosphere.

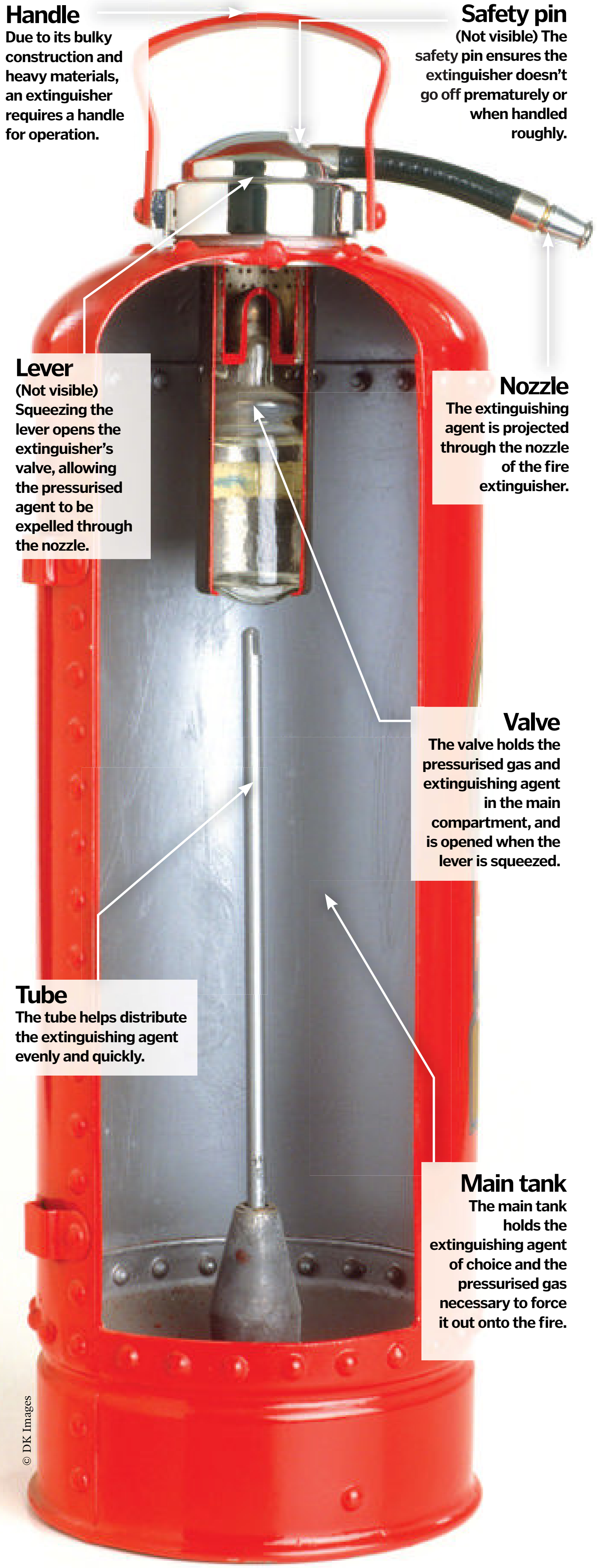
The modern pressurised fire extinguisher we are familiar with today was created in 1818 and consisted of a three-gallon copper vessel of a potassium carbonate solution contained within compressed air.

© Amerex Corporation

A typical, internally pressurised fire extinguisher, found in most private homes

© ADwarf

A rare cartridge-based fire extinguisher, used mainly in industrial environments


© DK Images

Handle
Due to its bulky construction and heavy materials, an extinguisher requires a handle for operation.

Safety pin
(Not visible) The safety pin ensures the extinguisher doesn't go off prematurely or when handled roughly.

Lever
(Not visible) Squeezing the lever opens the extinguisher's valve, allowing the pressurised agent to be expelled through the nozzle.

Nozzle
The extinguishing agent is projected through the nozzle of the fire extinguisher.

Valve
The valve holds the pressurised gas and extinguishing agent in the main compartment, and is opened when the lever is squeezed.

Tube
The tube helps distribute the extinguishing agent evenly and quickly.

Main tank
The main tank holds the extinguishing agent of choice and the pressurised gas necessary to force it out onto the fire.

Dyson Air Multiplier

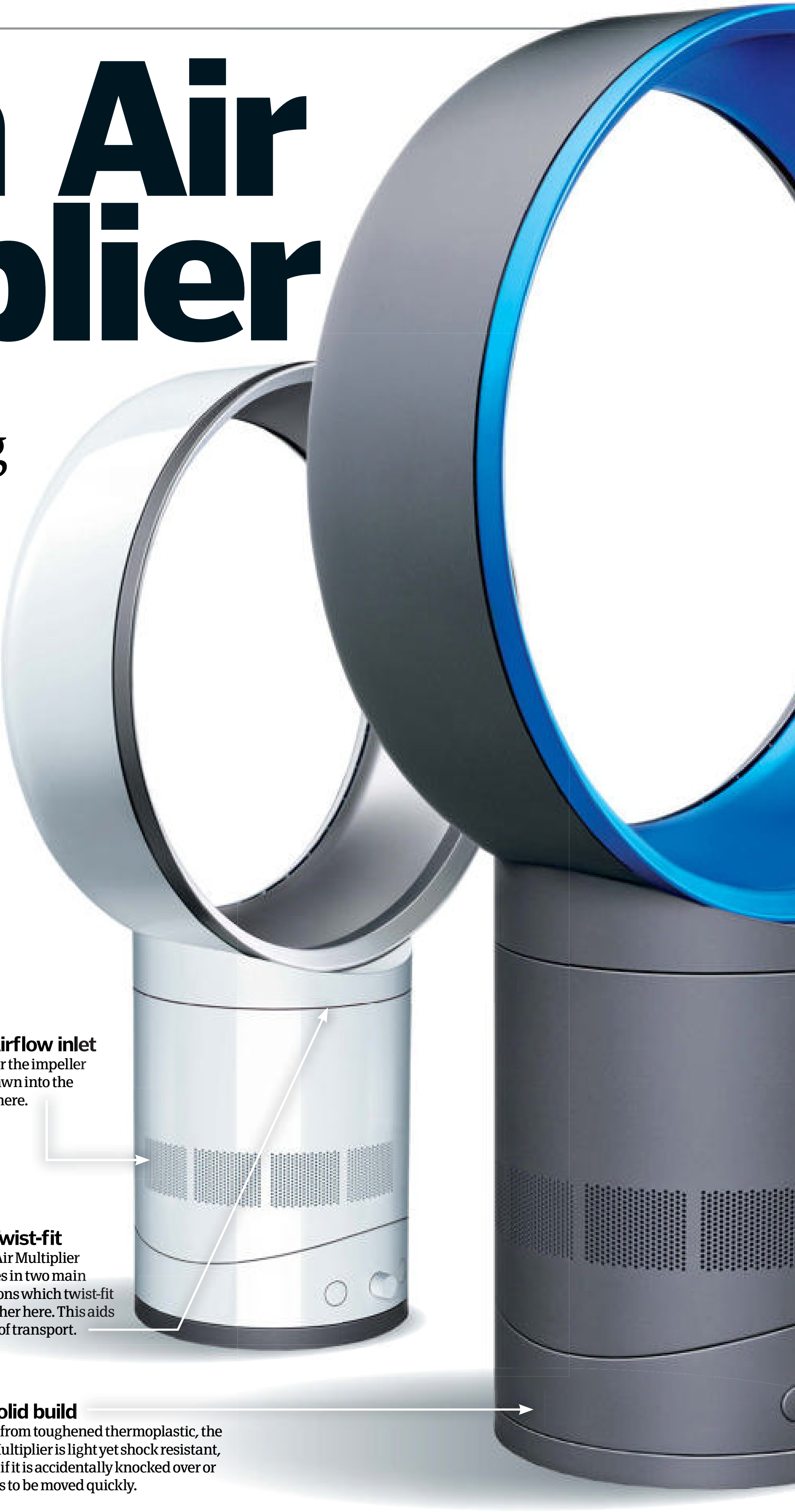
Bladeless, tiltable and hygienic – introducing the future of fan technology

When first created back in the late 19th Century, electrically powered mechanical fans were all the rage. However, due to their basic design and physical components, accidents involving their fast rotating blades soon became common, with children and adults alike injuring themselves. Luckily, today we have inventor extraordinaire Sir James Dyson, who is branching out from the vacuum cleaner and delivering the next stage in fan technology with the Dyson Air Multiplier, a 100 per cent bladeless fan with awesome cooling capabilities.

The Air Multiplier draws in air at its base using a mixed flow impeller similar to those found in turbochargers and jet engines. It forces it into the loop amplifier where it is pushed through a 3mm aperture and accelerated over a 16 degree airfoil-shaped ramp. As the air passes over the ramp it speeds up and draws more air in from behind, in a phenomenon know as inducement. As the air continues to move forward it also entrains more air from the surroundings. This means that it amplifies the air 15 times, expelling 400 litres of cool, smooth and uninterrupted air every single second.

The cone of air that is flowed outwards from the Air Multiplier is continuous, as it is not dictated by any rotating blades. This eliminates the buffeting effects users would traditionally receive if sitting too close to a fan or if it was on a high setting, being continuously pummelled by a series of air waves. Due to the nature of the airflow generation of the Air Multiplier, however, the cooling effects received are continuous and uninterrupted.

Design-wise the Air Multiplier is created with ease of use and portability at the fore, something represented in its clean, minimalist styling. The unit's upper body can be tilted forwards and backwards by 20 degrees – something aided by the motor being near the structure's centre of gravity, allowing minimal force to be expended to operate – and the amplification loop can easily be detached from the base unit. Further, due to the unit's lack of protective grille or complex blade structure, cleaning the Air Multiplier is easy and helps minimise the amount of dust and dirt projected around its surrounding environment and onto its users.



5. Airflow inlet
Air for the impeller is drawn into the unit here.

4. Twist-fit
The Air Multiplier comes in two main sections which twist-fit together here. This aids ease of transport.

7. Solid build
Built from toughened thermoplastic, the Air Multiplier is light yet shock resistant, ideal if it is accidentally knocked over or needs to be moved quickly.

5 TOP FACTS
FANS

Anorak

1 Fans are highly collectable and in the US there is an Antique Fan Collectors Association. The materials from which the fans are made often make them more desirable.

Fan-tastic

2 The first mechanical fans were driven by belt systems powered by water wheels. By the turn of the 20th Century, heat convection fans fuelled by alcohol or oil were common.

Usurper

3 Unfortunately, sales of traditional fans have decreased over the past 40 years thanks to the proliferation of air conditioning units.

Heads-up

4 Philip Diehl created the first electric ceiling fan in 1882. In 2009, the Hunter Fan Company developed the very first ceiling fan/wireless speaker combo system.

Icenet

5 Hundreds of millions of fans are used in machines and computers, keeping them cool to maximise their computational ability, and often preventing them from overheating.

DID YOU KNOW? *The Dyson Air Multiplier expels 400 litres of air every second*

2. Safe and hygienic

Thanks to the smooth brushed coating and minimalist, open design, the Air Multiplier is simple and easy to clean. Plus, with no blades come no severed fingers.

1. No buffeting

Due to the absence of blades, the Dyson Air Multiplier is not privy to air buffeting, allowing a smooth and continuous flow of air.

6. Variable airflow

Traditional fans have limited speed settings, often proving either too powerful or too weak for users' preferences. The Dyson Air Multiplier, however, utilises an energy-efficient brushless motor that allows speed to be set much more precisely.

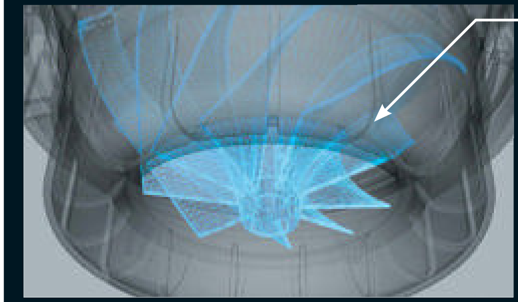
3. Touch-tilt

Unlike conventional top-heavy fans, which are built from weighty metals and plastics, the Air Multiplier is heavier at the bottom than at the top thanks to its ingenious design, and therefore can be tilted easily with a mere press of a finger.

Step-by-step cooling

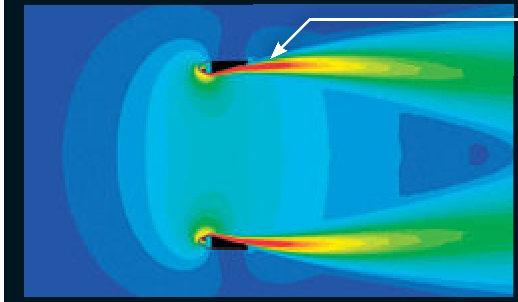
A visual guide to how the fan works

The secret to Dyson's Air Multiplier lies in its ingenious impeller-driven design, which not only generates airflow itself, but is also the catalyst for additional second and third-tier airflow multiplication. These five steps show how the Air Multiplier achieves this…



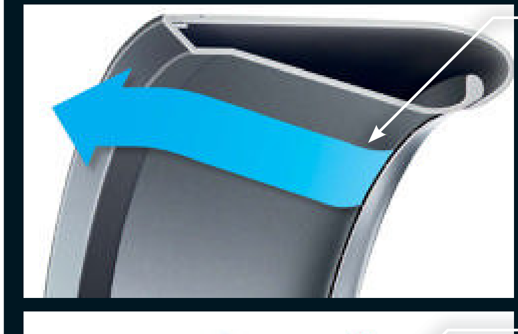
Step 1

The Air Multiplier's mixed flow impeller – a combination of technology used in turbochargers and jet engines – draws air into the base of the unit discretely and quietly.



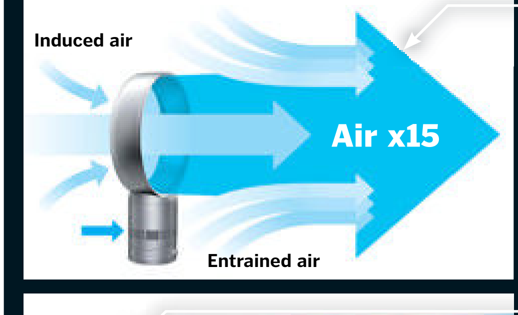
Step 2

The air is driven upwards through the unit's loop amplifier and is accelerated out through an annular aperture, creating a strong jet of air.



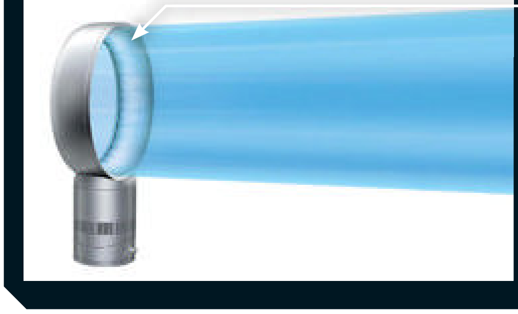
Step 3

Out of the aperture the air is then guided over a 16-degree airfoil-shaped ramp, accelerating and channelling its direction forwards.



Step 4

As the air passes over the ramp from the aperture, it draws in extra air from behind the unit (inducement), as well as even more air from in front of the fan (entrainment) once channelled outwards.



Step 5

The resulting airflow has been amplified 15 times and because there are no blades there is no buffering, resulting in a smooth column of air.

All Images © Dyson

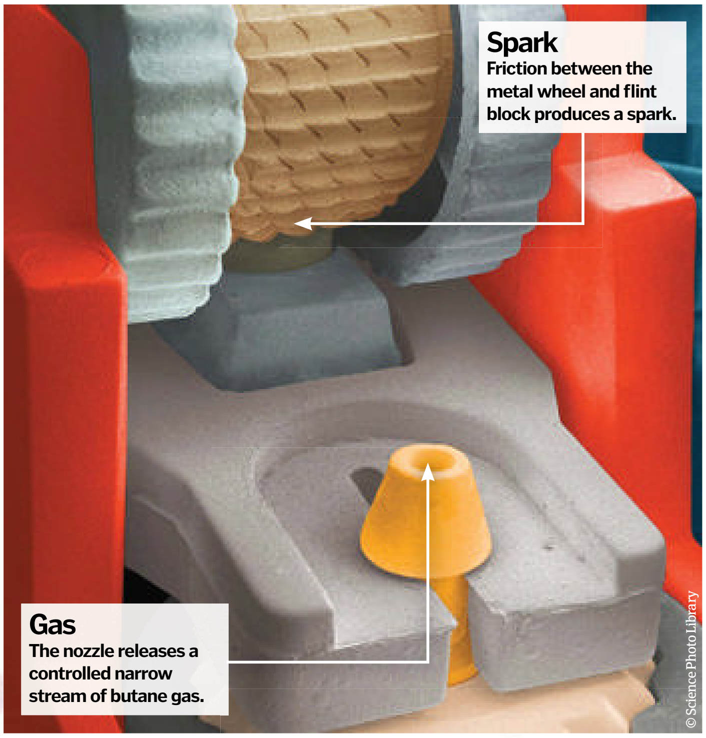
Disposable lighters

How are these miniature, portable flames produced?

Inside almost all modern disposable lighters is butane, used for its practical physical properties that make it a liquid at high pressure but a gas when released into the air. This means it can be stored as a liquid within the lighter, made of welded plastic to provide a high-pressure vessel. Decreasing the pressure by pressing a button and opening a hole allows a small amount of butane to escape in its gaseous state.

As butane is highly flammable, a small hot spark will ignite the narrow stream of gas and create a controlled flame. To create the spark a piezoelectric crystal generates an electric charge when compressed or struck by a small hammer in the lighter mechanism. This allows a voltage to be created between two wires and ignite the gas. Other lighters strike flint against a metal when a wheel is quickly turned with the thumb, causing friction and creating a spark.

© Sun Ladder



Spark
Friction between the metal wheel and flint block produces a spark.

Gas
The nozzle releases a controlled narrow stream of butane gas.

© Science Photo Library

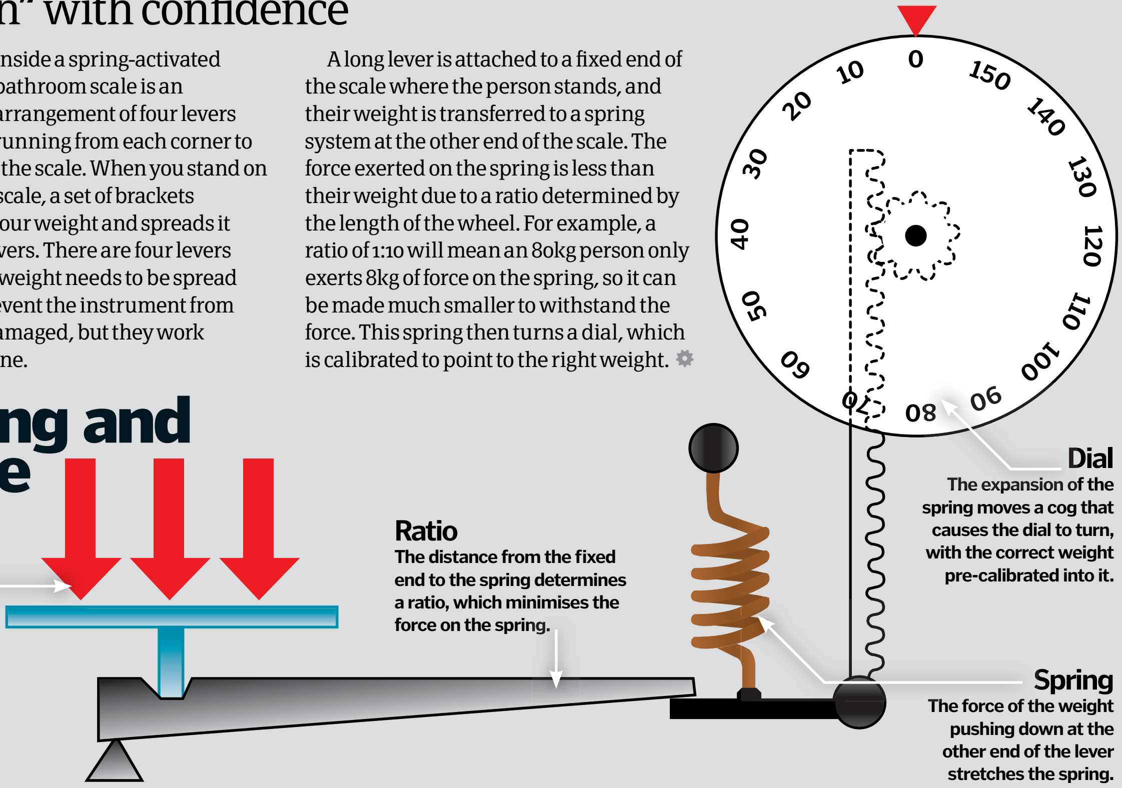
Bathroom scales

Now we can say "the scales must be broken" with confidence

Inside a spring-activated bathroom scale is an arrangement of four levers running from each corner to the centre of the scale. When you stand on a bathroom scale, a set of brackets distributes your weight and spreads it across the levers. There are four levers because the weight needs to be spread evenly to prevent the instrument from becoming damaged, but they work together as one.

A long lever is attached to a fixed end of the scale where the person stands, and their weight is transferred to a spring system at the other end of the scale. The force exerted on the spring is less than their weight due to a ratio determined by the length of the wheel. For example, a ratio of 1:10 will mean an 80kg person only exerts 8kg of force on the spring, so it can be made much smaller to withstand the force. This spring then turns a dial, which is calibrated to point to the right weight.

Spring and scale



Weight
A weight is applied to the scale very close to a fixed point to reduce the force exerted on the scale.

Ratio
The distance from the fixed end to the spring determines a ratio, which minimises the force on the spring.

Dial
The expansion of the spring moves a cog that causes the dial to turn, with the correct weight pre-calibrated into it.

Spring
The force of the weight pushing down at the other end of the lever stretches the spring.

DID YOU KNOW? *In 1922 a refrigerator cost almost twice as much as a Model T Ford*

How your food stays cool

Refrigerators are one of the most vital household appliances, keeping food cool and fresh. But how do they work?

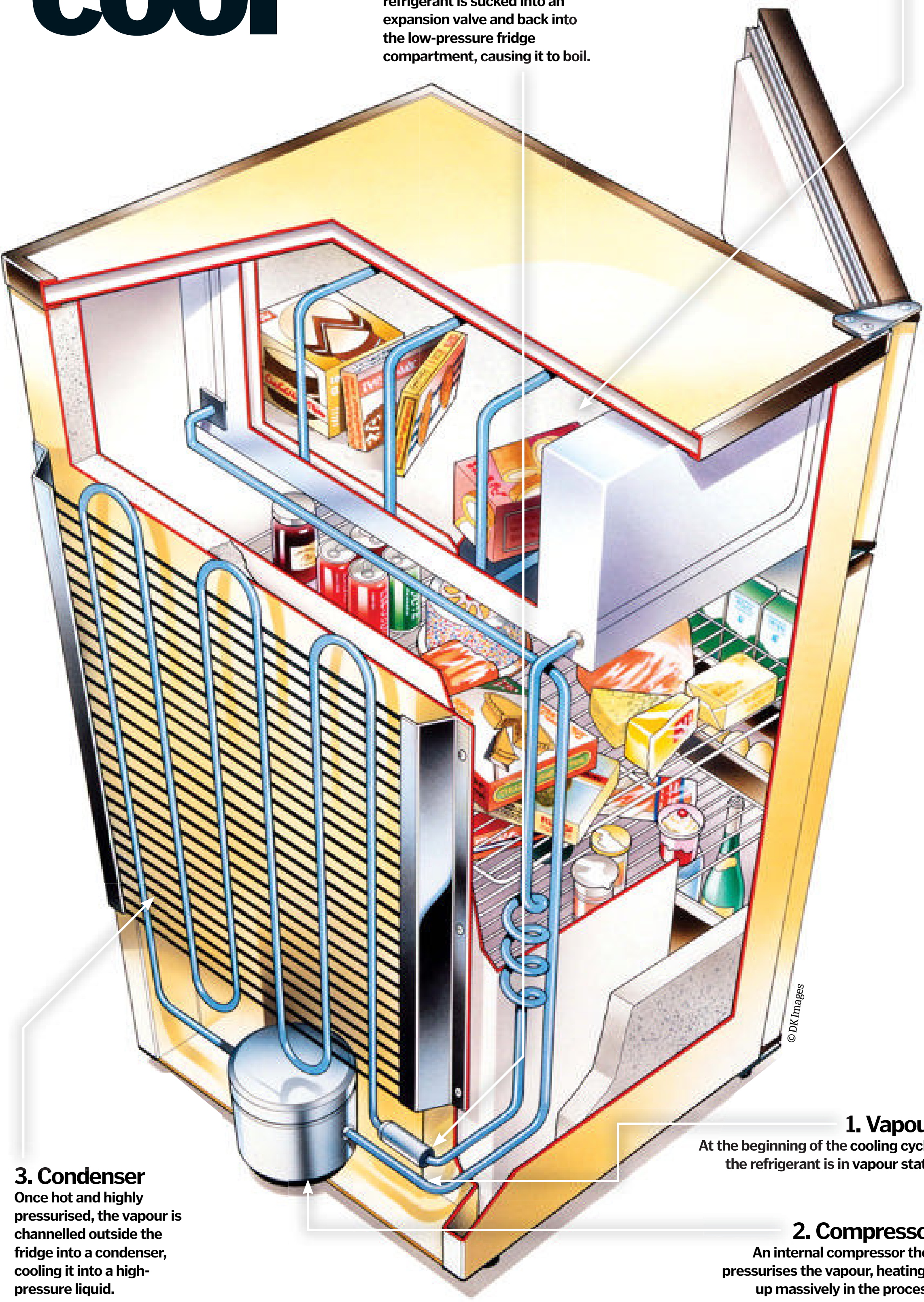
To achieve their cooling effect fridges rely on the simple notion of evaporation, absorbing heat when a liquid changes its state. This evaporation is the central principle of the refrigeration cycle, a perpetual loop in which a refrigerant is forced to change state in order to invoke heat absorption.

The cycle begins with the refrigerant in a vapour state, which is then pressurised in an internal compressor. This compression forces the refrigerant to heat up before being sent outside the fridge into a condenser and expelled into the surrounding area, cooling the refrigerant vapour in the process and condensing it into a highly pressurised liquid state.

This liquid is then sucked through an expansion valve and back into the low-pressure fridge compartment causing the refrigerant to boil (refrigerants have low boiling points), vaporise and drop in temperature, cooling the compartment in the process. The cycle then begins again, with the low-pressure refrigerant vapour being sucked up into the compressor.

Optimum fridge temperature is between 0 and 5°C

© Meggito



5. Compartment
As it boils (refrigerants have low boiling points) the refrigerant vaporises and cools the main compartment of the fridge before being sucked back into the compressor to begin the cycle again.

4. Expansion valve
Once condensed, the liquid refrigerant is sucked into an expansion valve and back into the low-pressure fridge compartment, causing it to boil.

1. Vapour
At the beginning of the cooling cycle, the refrigerant is in vapour state.

3. Condenser
Once hot and highly pressurised, the vapour is channelled outside the fridge into a condenser, cooling it into a high-pressure liquid.

2. Compressor
An internal compressor then pressurises the vapour, heating it up massively in the process.

© DK Images

> "A combination of electrical coils and magnetic fields within the toothbrush amplifies the power"

Electric toothbrushes

How these cleaning tools keep our mouths fresh and clean

An electric toothbrush removes plaque from teeth by moving its head back and forth up to 7,000 times a minute. An electrical charge produced by a small battery in the toothbrush vibrates and oscillates the head, allowing debris and plaque to be brushed out of the teeth and gums.

Rechargeable electric toothbrushes must be designed with exposure to water in mind. A technique known as 'inductive coupling' uses magnetic fields to stimulate the movement of an electric current throughout the toothbrush and allows the electrical components to remain sealed.

A combination of electrical coils and magnetic fields within the toothbrush amplifies the power, giving the head a much greater rotation speed. To recharge the batteries, electricity from a wall socket is stored within the electrical coils of the toothbrush.

When the toothbrush is turned on, rechargeable or not, the stored energy powers the motors within the toothbrush. A system of rods and wheels carries the motion up to the head of the toothbrush, making it rotate back and forth.

Head
The head can move back and forth up to 7,000 times a minute.

Motor mouth
Motorised rods and wheels make the head move back and forth getting into all the nooks and crannies.

Charger
Inductive coupling uses magnetic fields to stimulate an electric current, enabling the toothbrush to be charged in a wet environment.

© Jonas Bergsten

5 TOP FACTS
TIPS FOR CLEANER TEETH

1 Regular
Teeth should be brushed at least twice a day, or after every meal if possible. Brushing your tongue can also freshen breath.

2 Gone in 120 seconds
You should always brush your teeth for no less than two minutes to ensure as much plaque as possible is removed.

3 Quadrants
30 seconds should be spent on each quarter of the mouth. Thoroughly brush the inside, outside and top of each tooth.

4 Floss
After brushing your teeth, flossing will remove additional debris or plaque a toothbrush has missed between the teeth.

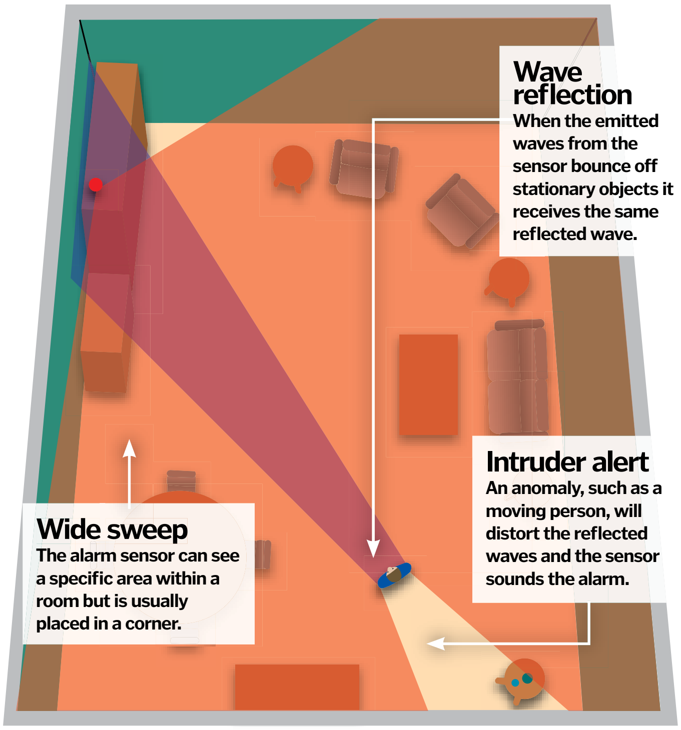
5 Dentist
Even following a strict brushing and flossing regime, it is still advisable to visit your dentist once every six months.

Burglar alarms

How do motion control systems in our homes detect intruders?

There are two main types of security system used in the home. The first is an alarm sensor that uses a radar-based motion detector. It sits in the corner of a room and sends out regular bursts of ultrasonic sound waves or microwave radio energy and detects the wave bouncing back. However, if an irregular object such as a person has entered the room, the reflected wave is distorted and the sensor sends a signal to the control panel to sound the alarm.

The other type is an infrared sensor. This device can detect movement in a room by sensing a change in infrared radiation given off by a person within an environment. It is calibrated to human body temperature, and when anomalous radiation enters from a human it knocks electrons within the sensor out of alignment. This triggers an electronic pulse, setting off the alarm. However, standing still will not trigger the alarm as it only responds to changes in infrared energy.



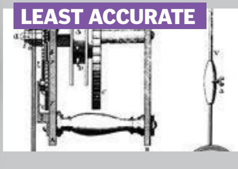
Wave reflection
When the emitted waves from the sensor bounce off stationary objects it receives the same reflected wave.

Wide sweep
The alarm sensor can see a specific area within a room but is usually placed in a corner.

Intruder alert
An anomaly, such as a moving person, will distort the reflected waves and the sensor sounds the alarm.

Head to Head
TYPES OF CLOCK

LEAST ACCURATE



1. Early mechanical clocks
Before 1657, mechanical clocks used crude balance wheels that lost up to an hour a day.

MORE ACCURATE

2. Digital watches
Digital watches use quartz crystals, which not only makes them more accurate but removes the need for moving parts.

MOST ACCURATE

3. Atomic clock
Atomic clocks use changes in the microwave signals emitted by atoms when they change energy levels. They won't gain or lose a second for millions of years.

DID YOU KNOW? *The word 'clock' is derived from two Celtic words: claggan and clocca, which means 'bell'*

Clock mechanics

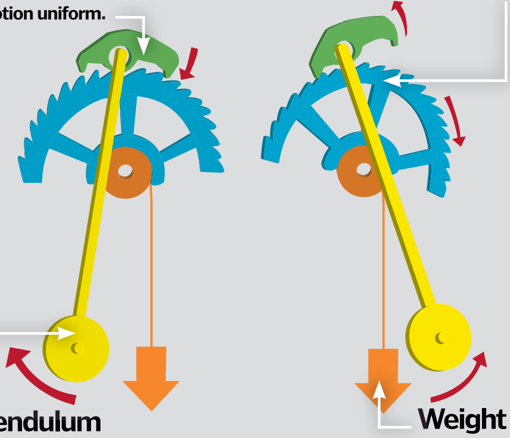
Discover the technology driving one of humanity's most useful inventions

It's no surprise that the basic principle of clock work has remained the same for centuries: oscillation. Whether a clock is powered by water, a spring or a battery it tells the time by measuring the repeated movement of a component called an oscillator. This repeats the same motion over and over in exactly the same way, each of which is called a beat. Attached to the oscillator is a controller (a component that supplies energy to replace that which the oscillator loses due to friction) this is provided to the controller in turn by a power supply – be that a pendulum, a battery or someone winding it. Finally, each beat is converted into a pulse that – when chained together – measures time in seconds, minutes, hours and so on.

Clock displays vary depending on the type of clock. Analogue examples use a 12-number clock face to indicate the hour, as well as minutes and seconds with the addition of an extra hand each. Digital clocks display the time using numbers only, and commonly use the 24-hour scheme, which measures midnight as 00:00 and each hour past it as 1, 2, 3am and so on.

Pendulum clocks aren't just one of the most elegant types, they were also the world's most accurate type of clock for over two centuries. Christiaan Huygens invented the pendulum clock – where a metal pendulum is used as the oscillator – in 1656, inspired by work done by Galileo. Galileo had discovered that a pendulum would swing at approximately the same speed regardless of size. In fact, he'd even made plans for a pendulum clock but died before he could complete them. Huygens combined this with his own discovery that a smaller swing meant the clock kept better time to create a mechanism that became accepted worldwide for over 200 hundred years.

The pendulum



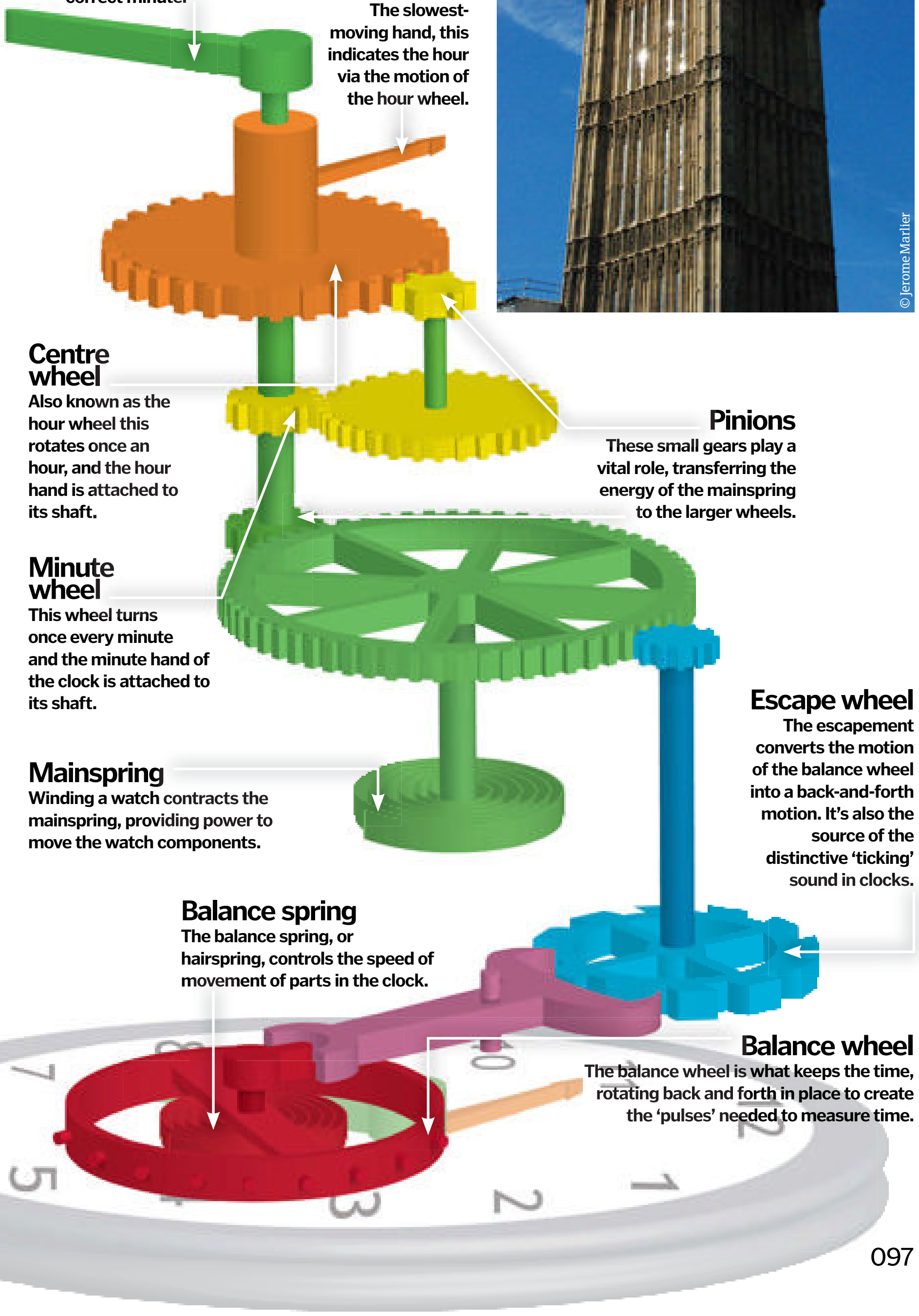
Anchor
This allows the motion of the pendulum to move the escape wheel along but keeps the motion uniform.

Escape wheel
This converts the motion of the pendulum into the energy used to move the clock hands.

Pendulum
The pendulum is the oscillator, its motion used to measure units of time.

Weight
The motion of the weight creates the oscillation of the pendulum.

The clock mechanism



Minute hand
Attached to the minute wheel, this uses the motion of that wheel to show the correct minute.

Hour hand
The slowest-moving hand, this indicates the hour via the motion of the hour wheel.

Centre wheel
Also known as the hour wheel this rotates once an hour, and the hour hand is attached to its shaft.

Pinions
These small gears play a vital role, transferring the energy of the mainspring to the larger wheels.

Minute wheel
This wheel turns once every minute and the minute hand of the clock is attached to its shaft.

Escape wheel
The escapement converts the motion of the balance wheel into a back-and-forth motion. It's also the source of the distinctive 'ticking' sound in clocks.

Mainspring
Winding a watch contracts the mainspring, providing power to move the watch components.

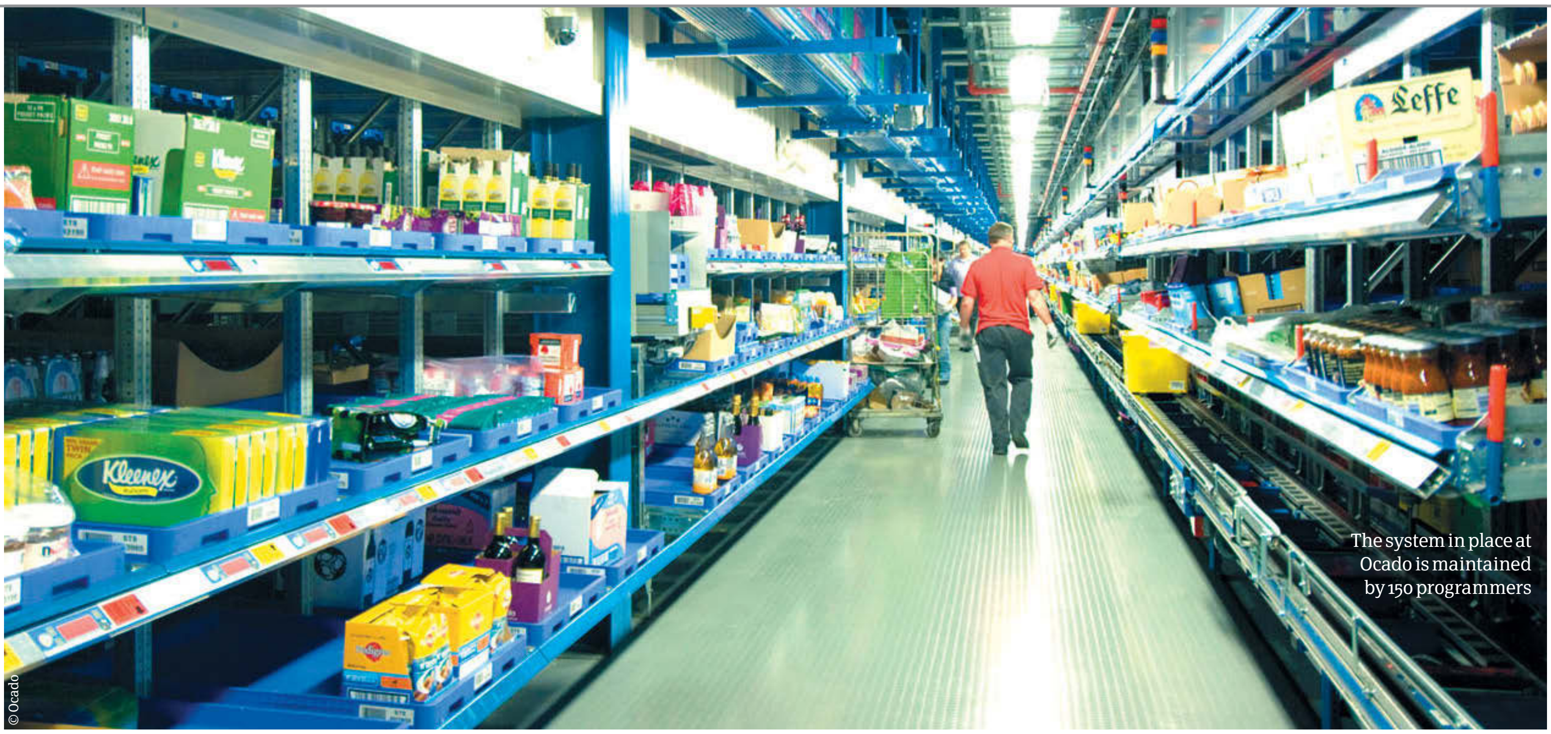
Balance spring
The balance spring, or hairspring, controls the speed of movement of parts in the clock.

Balance wheel
The balance wheel is what keeps the time, rotating back and forth in place to create the 'pulses' needed to measure time.

Big Ben's pendulum is protected inside a wind-proof box beneath the clock room

© Jerome Marlier

> "The heart of Ocado's operation is its central distribution warehouse"


The system in place at Ocado is maintained by 150 programmers

© Ocado

Grocery shopping online

With the UK's foremost online supermarket Ocado approaching its tenth anniversary, check out the technology and systems used to get groceries to your door

Online supermarkets that deliver produce to customers via the web are growing in popularity. With no high-street stores, retailers like Ocado rely on a web-based interface that's directly linked to a huge automated warehouse. This allows customers to select their groceries remotely from their computer, or through their smartphone with a special app. Delivery is then scheduled for home transit.

The heart of Ocado's operation is its central distribution warehouse, an automated hub of activity that revolves around a state-of-the-art, ten-mile-long conveyor belt system. The robotic conveyor belt is controlled by a central software-guidance system that directs colour-coded crates through the depot's aisles. Each container is fitted by the system with three open plastic bags and is routed to pass selected produce, according to their barcodes. The system also determines packing patterns – with heavier goods packed at the bottom of bags – as well as the order in which crates should be loaded into transit vans, dependent on delivery time.

Transit to a customer's home is handled by a series of custom-built Mercedes-Benz vans, each with air conditioning to help maintain produce freshness during transit. Routes are co-ordinated from Ocado's communications hub, where computer software liaises with GPS satellites to plan an optimal delivery path according to local traffic conditions and distance to target. If a delivery is located at an elongated distance from the central warehouse, orders are carried to smaller, local hubs, then passed over to region-specific vehicles for final delivery.

Online shopping step-by-step

1. User interface

Storefronts are web interfaces, directly accessible by personal computers and smartphones. They allow customers to search textually and visually for products, as well as book a delivery slot. Sites often include video recipes, product bundles and price comparison stats.

2. Produce

Online supermarkets source produce directly from individual companies, as well as brand ranges from notable high-street shops. This produce then arrives in bulk to a central pick and packing warehouse.

© Ocado

3. Warehouse

The centre of operations is the distribution warehouse, usually a semi-automated conveyor belt system that sorts orders. The system software is linked to the user interface, receiving orders from customers for picking as well as updating stock levels.

4. Shipping

Product shipping is usually handled by air conditioned vans to ensure that groceries remain fresh during transit. Vans proceed from the warehouse directly to a user's home or, if distance is lengthy, to a local distribution hub for secodary onward transit.

© Garmin
Home 15 Min.
GARMIN

5. Communication

Van transit is conducted via GPS link to a communications hub, where routes are planned and updated remotely, taking advantage of traffic updates and accident reports. This allows for specific time slots to be granted.

Water coolers

How do these mainstays of the office environment serve cold drinks?

There are two techniques used to cool water that are in mainstream use. The preferred method is to use a refrigerant within the cooler to chill the water, but a thermoelectric method can also be used.

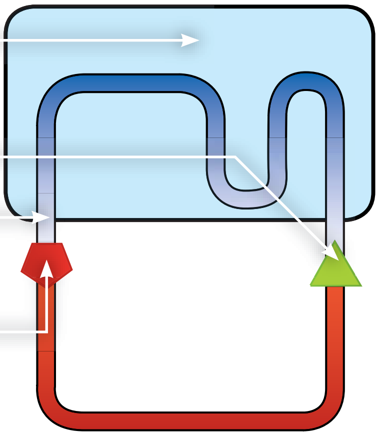
Both types of water cooler store a certain amount of water in a reservoir within the machine. Refrigerant water coolers use a compressor in tandem with a refrigerant, in many cases the product Freon developed by DuPont.

This product has the ability to absorb heat. Freon is compressed into a gas, which soaks up the heat surrounding the reservoir, cooling the water. As water is dispensed from the reservoir it is automatically refilled to begin the cooling process again.

A thermoelectric water cooler employs the Peltier effect to cool the water. As current passes from one material to another, heat energy can be absorbed into a conducting material. This cools the water, although it is less effective in hot locations than refrigerant cooling.

The perfect place for gossip and refreshment

A refrigeration cooling system



Reservoir
Water is stored in the reservoir to be cooled to a suitable temperature.

Expansion
The refrigerant is expanded into a gas and travels through the reservoir, absorbing heat.

Transfer
The gas then transfers the heat out the reservoir.

Compressor
A refrigerant fluid – usually Freon – is compressed and passed through a sealed regenerating system.

DID YOU KNOW?
Halsey Willard Taylor and Luther Haws invented the first drinking fountains in the early-20th Century.

5 TOP FACTS
WATER

1 Water is remarkably heavy considering it's made up of two gasses – especially when one of them is the lightest substance in the universe.

2 Water can turn into vapour even at freezing point.

3 It's thought Earth's water erupted from volcanoes billions of years ago, forming vapour in the atmosphere and then raining as water as the planet cooled.

4 The three atoms in a water molecule – two hydrogen and one oxygen – are held together by electrostatic charges.

5 20,000-year-old water exists in reservoirs beneath the Sahara.

© Pengo

A solar charger for renewable batteries, a clever invention indeed

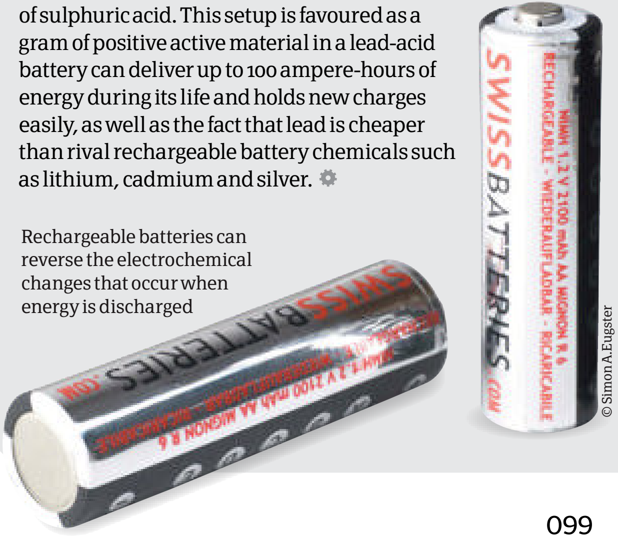
Rechargeable batteries explained

How do they accept and store new energy?

Unlike primary cell batteries, which have to be discarded once discharged, rechargeable secondary cell batteries can be supplied with direct current and recharged to near original levels. Secondary cells can restore electrical energy as, unlike primary cells, their electrochemical reactions are electrically reversible, so when a direct current voltage that is larger than the battery's original is applied in the opposite direction to its discharge direction, electrons are driven back through the charging circuit into the battery's electrodes and chemical innards.

The most widespread chemical composition of rechargeable batteries is lead-acid, where the battery's plates, such as the positive electrode at the top of the battery, is coated with lead dioxide and the electrolyte – the liquid innards of the battery containing free ions that carries current – composed of sulphuric acid. This setup is favoured as a gram of positive active material in a lead-acid battery can deliver up to 100 ampere-hours of energy during its life and holds new charges easily, as well as the fact that lead is cheaper than rival rechargeable battery chemicals such as lithium, cadmium and silver.

Rechargeable batteries can reverse the electrochemical changes that occur when energy is discharged


SWISSBATTERIES.COM
NiMH 1,2 V 2100 mAh AA MIGNON R 6
RECHARGEABLE - WIEDERAUFLADBAR - RICARICABILE
© Simon A.Eugster

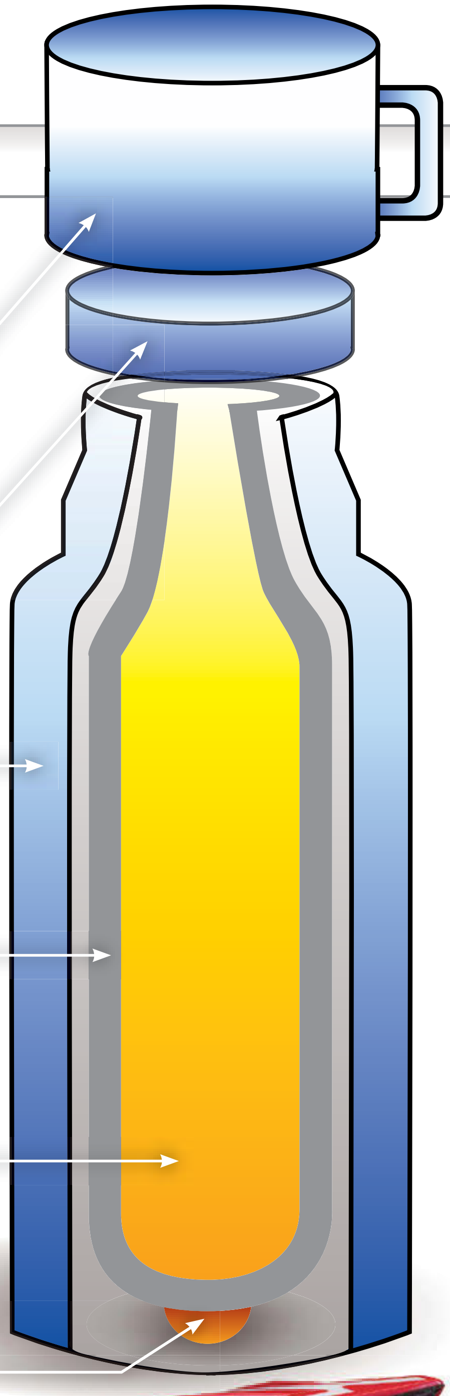
What's inside a vacuum flask?

How does the science of vacuums help this container keep hot things hot and cold things cold?

Vacuum flasks use thermodynamic principles to keep the hot or cold contents of a vessel warmer or cooler than the temperature outside. A glass of cold water left on a table will eventually warm up till it's room temperature, and likewise a hot cup of coffee will cool down until it's the same temperature as the room. Creating a vacuum between the contents in a sealed vacuum flask and the outside environment provides thermal insulation, preventing heat transfer and therefore temperature change.

Because there are so few atoms inside a vacuum, heat transfer via conduction and convection is limited, meaning that the temperature within the flask remains the same for longer. The heat will eventually become the same temperature as that of the outside environment, but only really through the weaknesses of the seal at the top of the vessel and in the cap.

Inside a vacuum flask



5. Cup
A handy cup is usually screwed on the top of the flask.

1. Cap
The only place where heat transfer can potentially take place is through the limitations of the seal.

2. Outer casing
The outer materials are made of either metal or plastic and serve to protect the fragile inner glass.

3. Vacuum layer
A double-walled glass envelope contains a vacuum that forms a barrier separating the inner content from the temperature outside.

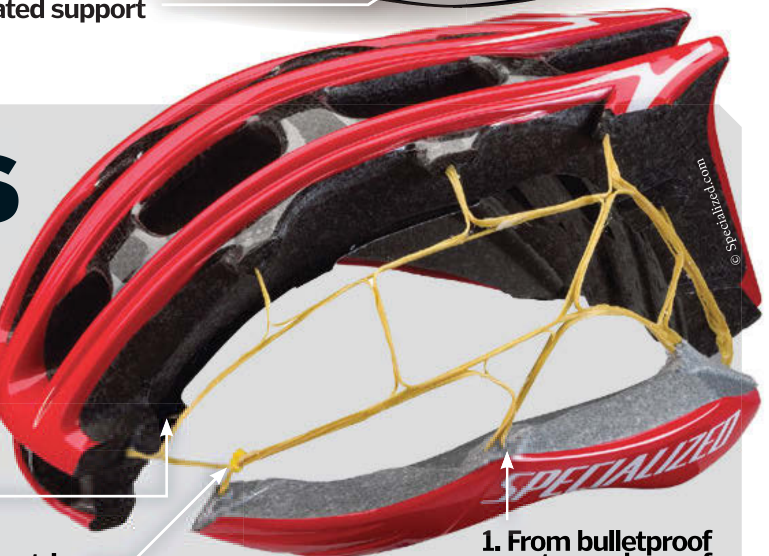
4. Contents
The hot or cold contents will maintain the same temperature for far longer inside a vacuum flask.

Insulated support

Cycle helmets

Keeping your head protected

Six thousandths of a second. A tiny fragment of time but in a bike crash it can mean the difference between life and death. Bike helmets contain a layer of crushable foam designed to collapse during a crash and not only cushion your head from the impact but slow it down by six thousandths of a second. That's enough to reduce the peak impact on your brain, the moment of force where your head hits the road or another hard surface. Without a helmet, that impact can lead to serious brain injury but with one, the impact is cushioned enough to stop your brain being pulled around by internal nerves and blood vessels being acted on by the forces of the crash.



© Specialized.com

3. Close fit
Padding at the front and rear of the helmet makes it more comfortable to wear and ensures it fits properly.

2. Protective matrix
The Kevlar matrix that runs through this helmet's structure may seem thin but it provides vital protection.

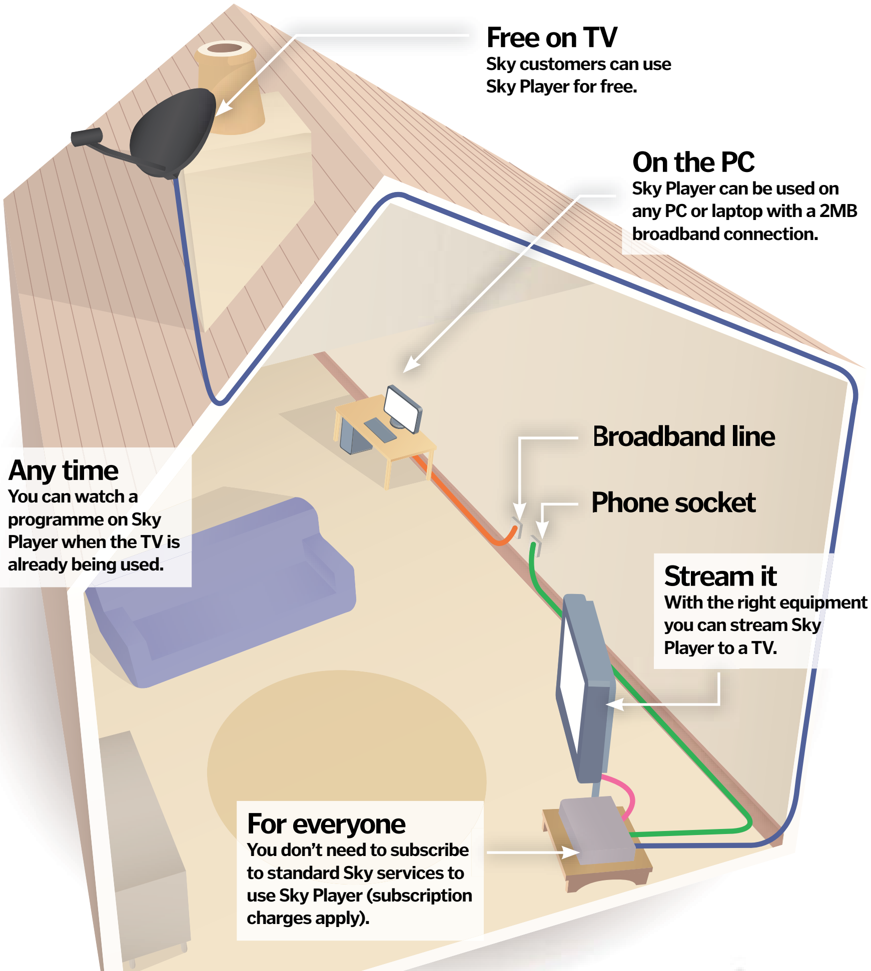
1. From bulletproof to crash proof
Kevlar isn't just an action hero's best friend any more. This helmet uses the substance to provide extra protection.

How does Sky Player deliver TV?

Sky Player delivers live TV over the internet continuously. So, how does it do it?

Sky Player is a spin-off from Sky's main set-top box service which delivers live TV to computers and the Xbox 360 on demand to anyone who wants to use it. Customers can stream live TV from a selection of more than 40 channels and can also catch up on TV shows they may have missed for up to 30 days.

The process behind the system is surprisingly simple and is centred on racks of PCs in a dedicated server room which act as the hub of the operation. Shows are uploaded in three formats – MPEG-2, QuickTime and Windows Media – onto an FTP server where they are encrypted to ensure that only valid subscribers can view them. At this point the Sky Player software will push requests direct to it for streaming on the user's equipment. With thousands of requests live at any one time the bandwidth consumed is huge by any standards. In short, the system works by delivering digital information like most other internet services such as websites, but the security involved and the equipment required to deliver such a huge amount of content is without doubt at the high-end of what is possible today.



Free on TV
Sky customers can use Sky Player for free.

On the PC
Sky Player can be used on any PC or laptop with a 2MB broadband connection.

Any time
You can watch a programme on Sky Player when the TV is already being used.

Stream it
With the right equipment you can stream Sky Player to a TV.

For everyone
You don't need to subscribe to standard Sky services to use Sky Player (subscription charges apply).

The Player is a spin off from the set-top service

A brief history

Sky can trace its roots all the way back to 1982 and some significant milestones have been achieved since

1982
Super Station Europe makes its first broadcast to cable customers in Norway and Finland. Two years later it becomes 'Sky Channel'.

1990
British Sky Broadcasting is formed following a merger between Sky Television and British Satellite Broadcasting.

1992
British Sky Broadcasting signs exclusive rights to the FA Premier League and brings live football to the masses for the first time.

1998
Astra satellites launched which pave the way for Sky Digital to provide digital satellite television across the country.

2001
Sky+ launches which offers digital video recording alongside the ability to pause and rewind live TV.

2006
Sky HD launches with ten high definition channels. Sky expects 50 HD channels to be available by the end of 2010.

2009
Sky Songs launches offering MP3 downloads on a subscription basis and unlimited streaming of over 4 million tracks.

2010
The Sky 3D channel is the latest innovation in Sky's short, but fascinating history.

How do aerosol sprays work?

Understanding how these cans work well under pressure…

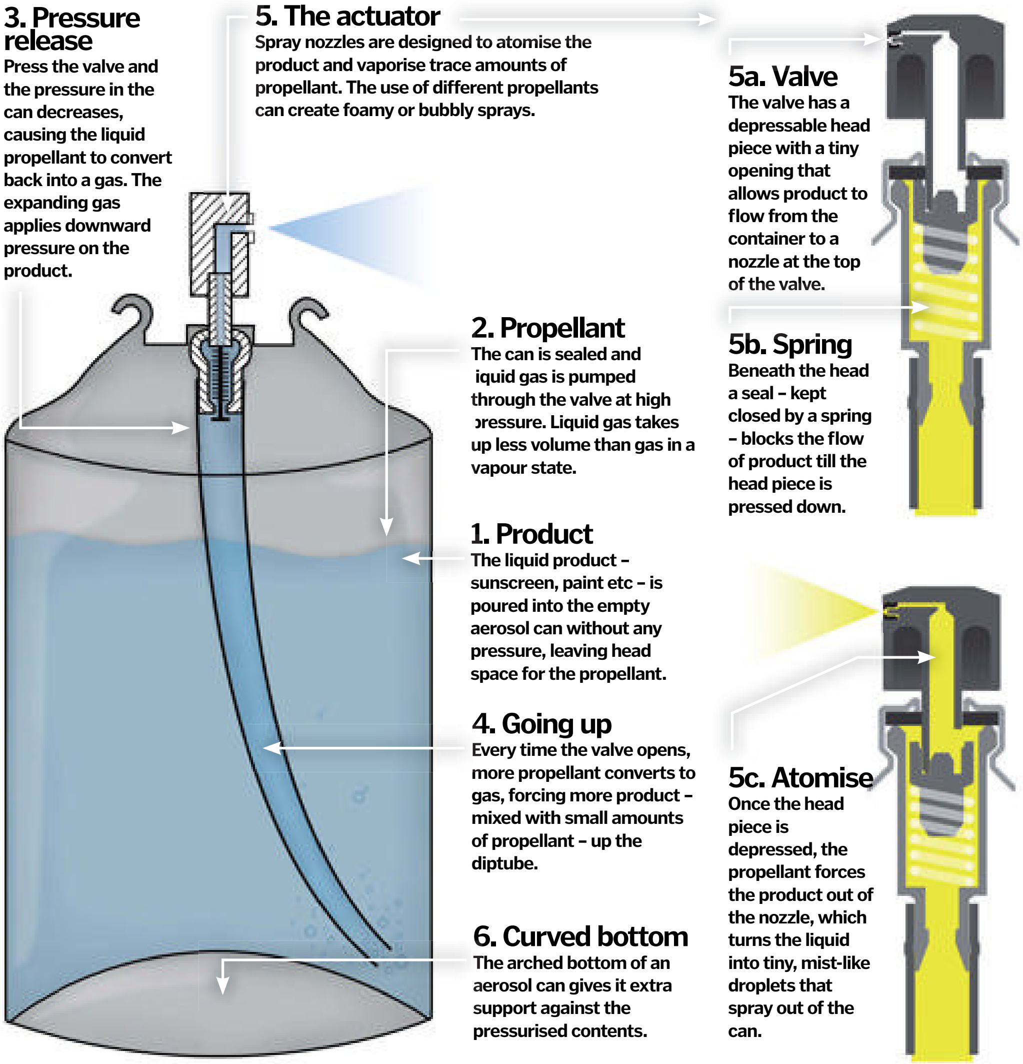
Inside an aerosol spray can are two fluids: propellant and product. The propellant is actually a gas under very high pressure, which squeezes it into a liquid state. This pressurised propellant is the engine inside an aerosol can.

To understand how this process works, start with an empty aluminium aerosol can. Pour in the product – hair spray, cooking oil, shaving cream etc – about two-thirds to the top of the can. Seal the can with a valve attached to a 'diptube', a straw that extends to the bottom of the can.

Now pump in the liquid gas under high pressure to fill the 'head space' of the can. When you press down on the valve, it reduces the pressure in the can, causing some of the propellant to 'boil' back into a gaseous state. As the gas expands, it forces the product up the diptube and out the 'actuator', a nozzle that atomises the product into tiny droplets.

©Bogdan

A tagger's ultimate weapon



3. Pressure release
Press the valve and the pressure in the can decreases, causing the liquid propellant to convert back into a gas. The expanding gas applies downward pressure on the product.

5. The actuator
Spray nozzles are designed to atomise the product and vaporise trace amounts of propellant. The use of different propellants can create foamy or bubbly sprays.

5a. Valve
The valve has a depressable head piece with a tiny opening that allows product to flow from the container to a nozzle at the top of the valve.

2. Propellant
The can is sealed and liquid gas is pumped through the valve at high pressure. Liquid gas takes up less volume than gas in a vapour state.

5b. Spring
Beneath the head a seal – kept closed by a spring – blocks the flow of product till the head piece is pressed down.

1. Product
The liquid product – sunscreen, paint etc – is poured into the empty aerosol can without any pressure, leaving head space for the propellant.

4. Going up
Every time the valve opens, more propellant converts to gas, forcing more product – mixed with small amounts of propellant – up the diptube.

5c. Atomise
Once the head piece is depressed, the propellant forces the product out of the nozzle, which turns the liquid into tiny, mist-like droplets that spray out of the can.

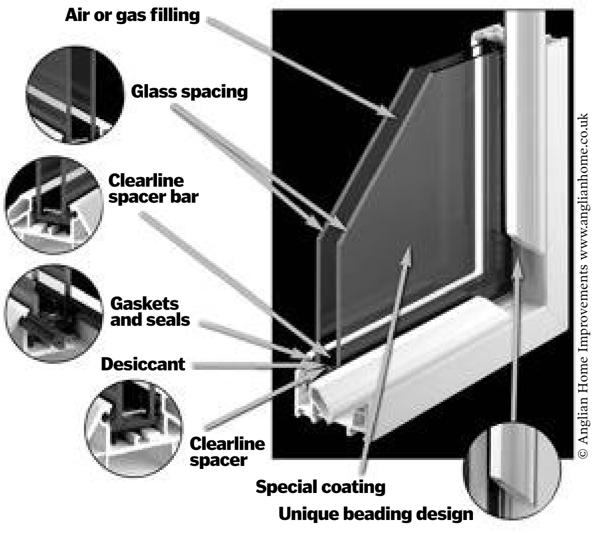
6. Curved bottom
The arched bottom of an aerosol can gives it extra support against the pressurised contents.

Double glazing

How does double glazing keep your house warm and are there any other reasons why we use it?

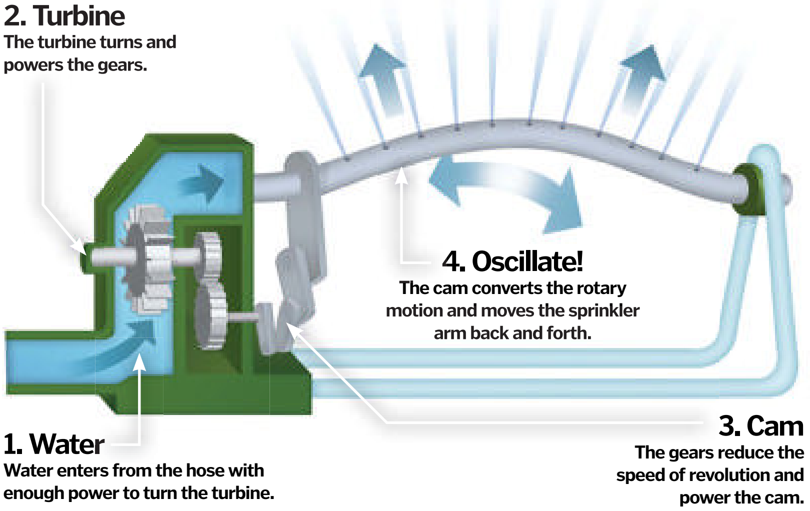
Double glazing in essence is trapped air between two separate panes of glass. The air in-between the sheets acts as an insulating buffer zone that prevents heat loss and gain.

Double glazing also serves as a sound barrier, reducing noise pollution. Double glazing is championed as a must-have of modern living over traditional single sheet windows, because it is less likely to suffer with condensation. Condensation occurs on single glass panels because the warm air inside the house is cooled on contact with the window by the cold outside air. With double glazing the insulation between the two acts as a barrier and prevents the transmission of air temperature therefore condensation is much less likely to occur.



© Anglian Home Improvements www.anglianhome.co.uk

DID YOU KNOW? *The first commercially sold impact sprinkler was called the 'Rain Bird'*


2. Turbine
The turbine turns and powers the gears.
4. Oscillate!
The cam converts the rotary motion and moves the sprinkler arm back and forth.
1. Water
Water enters from the hose with enough power to turn the turbine.
3. Cam
The gears reduce the speed of revolution and power the cam.

Sprinklers mechanics

How do oscillating sprinklers offer hands-free water distribution?

During summer lawn sprinklers are a common sight in yards and gardens the world over – so long as there's no hosepipe ban. The sprinkler is a simple but no-less ingenious device that harnesses the power of the water that it distributes to the lawn. The key to its success is a turbine and a cam.

So, the sprinkler is attached to a hosepipe, the water runs through the hosepipe and is sprayed from the sprinkler arm. But how does it move back and forth? Well, as the water enters it turns a turbine, usually a cylindrical, bladed piece of plastic. The force of the water turns the turbine at a very high rate, so a system of gears are employed to slow the revolution speed.

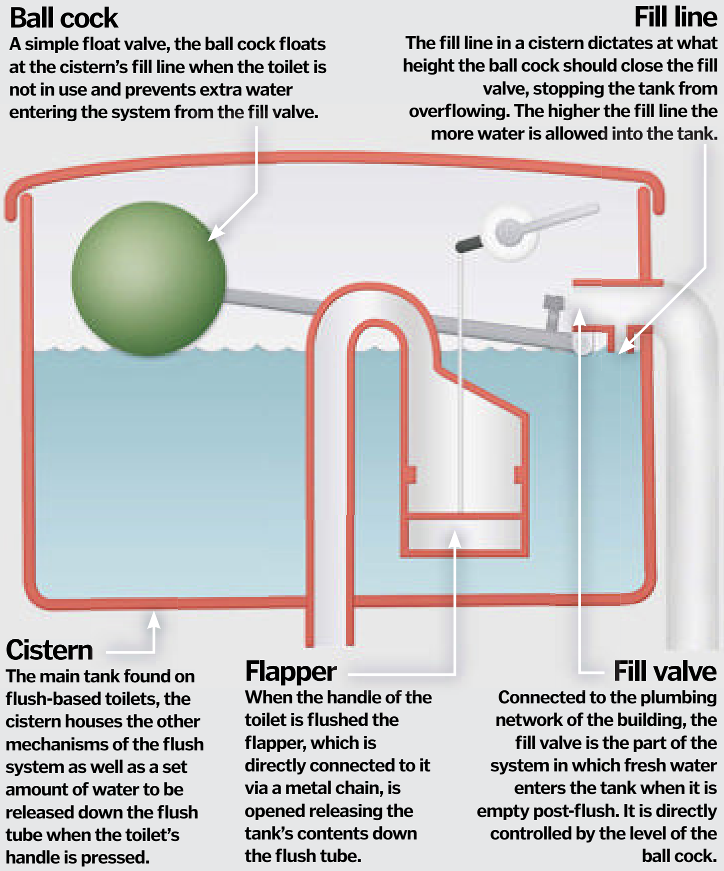
Once slowed the rotating motion needs to be transferred to a linear one so that the arm will move back and forth. This is achieved with the use of a cam. A cam can be an irregularly shaped wheel or other shape that produces a smooth reciprocating (back and forth) motion in the follower, which is a lever making contact with the cam. This back-and-forth motion is what causes the sprinkler arm to move and spray a fine arc of water across the surface of the lawn. ✻

Sprinklers can water the lawn and amuse the kids!

Ball cocks

How do they both refill and stop your toilet from overflowing?

A ball cock is a simple float valve that moderates the amount of water in your toilet's cistern. It both opens a water-in valve when the water level in your tank is low, and shuts off that valve when the water reaches a pre-set point called the toilet's fill line. A ball cock's construction is usually characterised by a hollow spherical plastic balloon on the end of a metal rod, which in turn leads to the cap of the flow valve. The plastic balloon sits on the surface of the tank's water at the fill line and when the toilet is operated and the water level in the tank reduces the balloon drops with it, lifting the valve cap in a seesaw motion. Only when the level of water in the tank is returned to the fill line does the ball cock rise to a level where the valve cap is replaced, shutting off the water supply. ✻

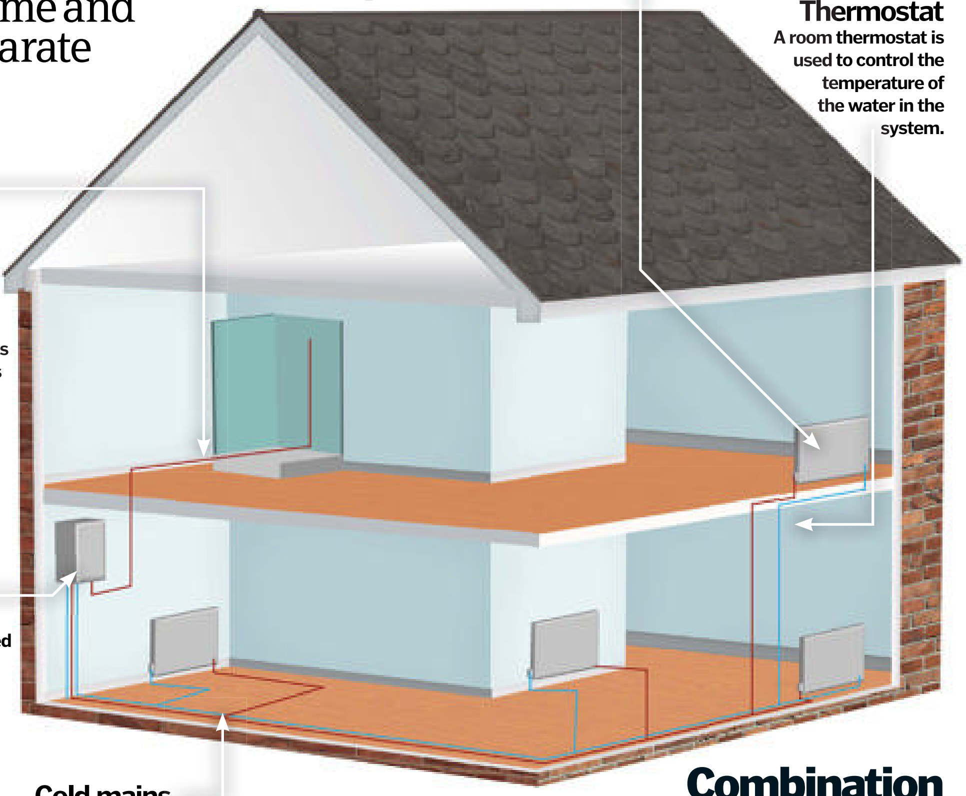

Ball cock
A simple float valve, the ball cock floats at the cistern's fill line when the toilet is not in use and prevents extra water entering the system from the fill valve.
Fill line
The fill line in a cistern dictates at what height the ball cock should close the fill valve, stopping the tank from overflowing. The higher the fill line the more water is allowed into the tank.
Cistern
The main tank found on flush-based toilets, the cistern houses the other mechanisms of the flush system as well as a set amount of water to be released down the flush tube when the toilet's handle is pressed.
Flapper
When the handle of the toilet is flushed the flapper, which is directly connected to it via a metal chain, is opened releasing the tank's contents down the flush tube.
Fill valve
Connected to the plumbing network of the building, the fill valve is the part of the system in which fresh water enters the tank when it is empty post-flush. It is directly controlled by the level of the ball cock.

Central heating

How a combi boiler heats your home and your water with no need for a separate hot water storage tank

The heat source for a central heating system is the boiler. 70 per cent of UK households now use a combination, or 'combi', boiler to heat their homes and their water – all in one compact unit. Inside the boiler, water is heated by a metal heat exchanger and pumped into a closed system of pipes that loop around the home to radiators in each room. By using a combi boiler, if you turn on your hot tap, water from the mains is heated as needed, with no need for a large and obtrusive storage cylinder.

All modern boilers fitted in the UK are condensing boilers, which are more fuel-efficient because they re-use the heat energy that, in a non-condensing boiler, would be expelled through the flue. The water is heated as it flows through the pipes inside one (or sometimes two) heat exchangers, which are suspended in hot gases over the burner's flames, maximising the heat transfer from the burner. In a combi, the temperature of the flue gases is reduced to 50-60°C (rather than the 120-180°C in a non-condensing boiler), and most of the gas leaves the flue as water vapour while the rest is drained away as condensate, or water.



Radiators
The temperature of a room's individual radiator can be controlled using a thermostatic radiator valve.

Thermostat
A room thermostat is used to control the temperature of the water in the system.

Hot water
Hot water is delivered at mains pressure. As soon as the hot tap is turned on, the water flow is detected by the gas burner, which uses electric sparks to ignite the gas that heats the water as it runs back and forth over a heat exchanger.

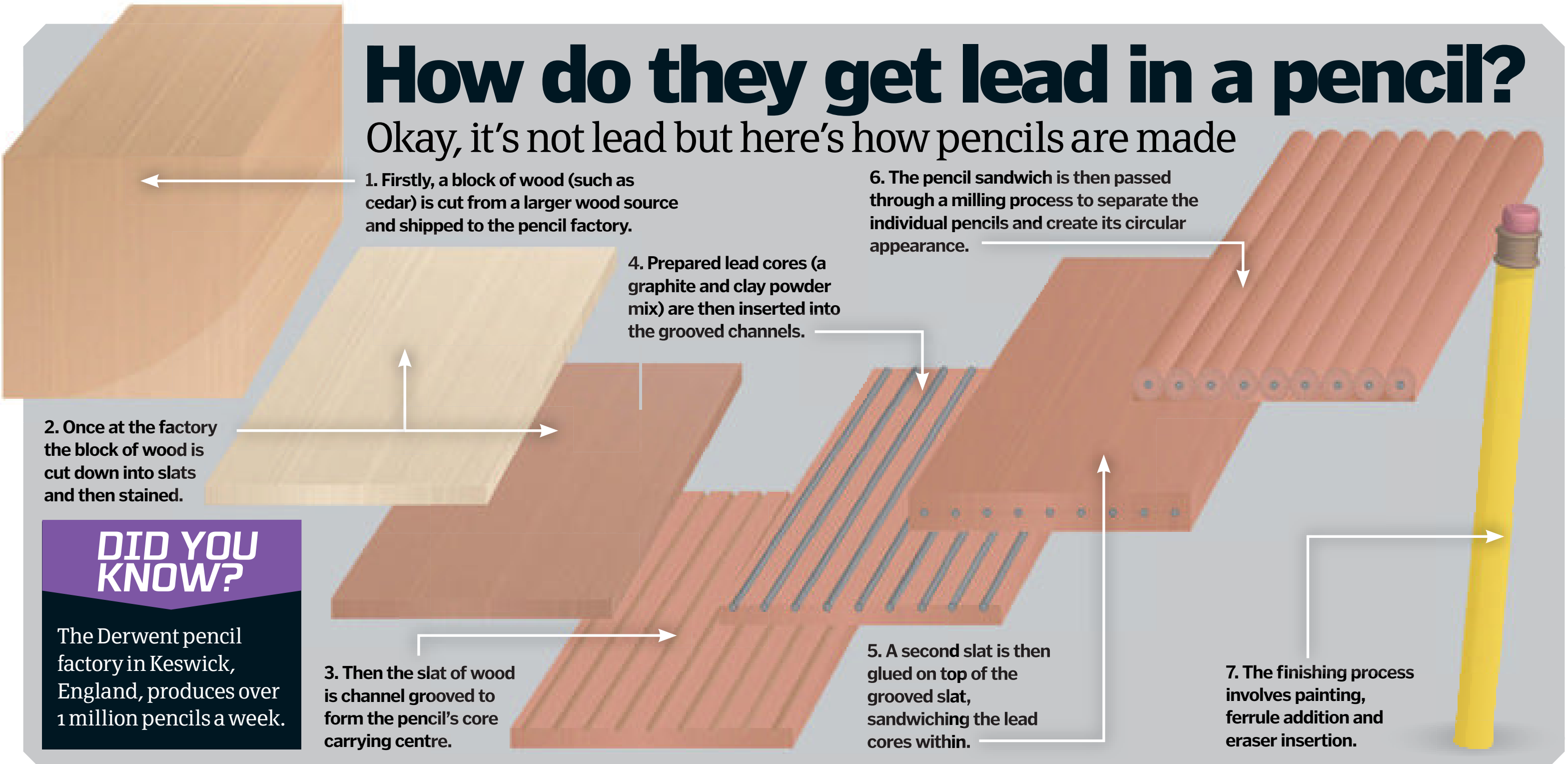
Boiler
The combi boiler can be programmed to switch the central heating on and off at desired times and at a specific temperature. A pump inside the boiler transports water through the radiators.

Cold mains
The combi heats water direct from the mains as and when it's required. There's no need for a coldwater storage tank.

Combination boiler central heating system

How do they get lead in a pencil?

Okay, it's not lead but here's how pencils are made



1. Firstly, a block of wood (such as cedar) is cut from a larger wood source and shipped to the pencil factory.

2. Once at the factory the block of wood is cut down into slats and then stained.

3. Then the slat of wood is channel grooved to form the pencil's core carrying centre.

4. Prepared lead cores (a graphite and clay powder mix) are then inserted into the grooved channels.

5. A second slat is then glued on top of the grooved slat, sandwiching the lead cores within.

6. The pencil sandwich is then passed through a milling process to separate the individual pencils and create its circular appearance.

7. The finishing process involves painting, ferrule addition and eraser insertion.

DID YOU KNOW?

The Derwent pencil factory in Keswick, England, produces over 1 million pencils a week.

Air conditioning

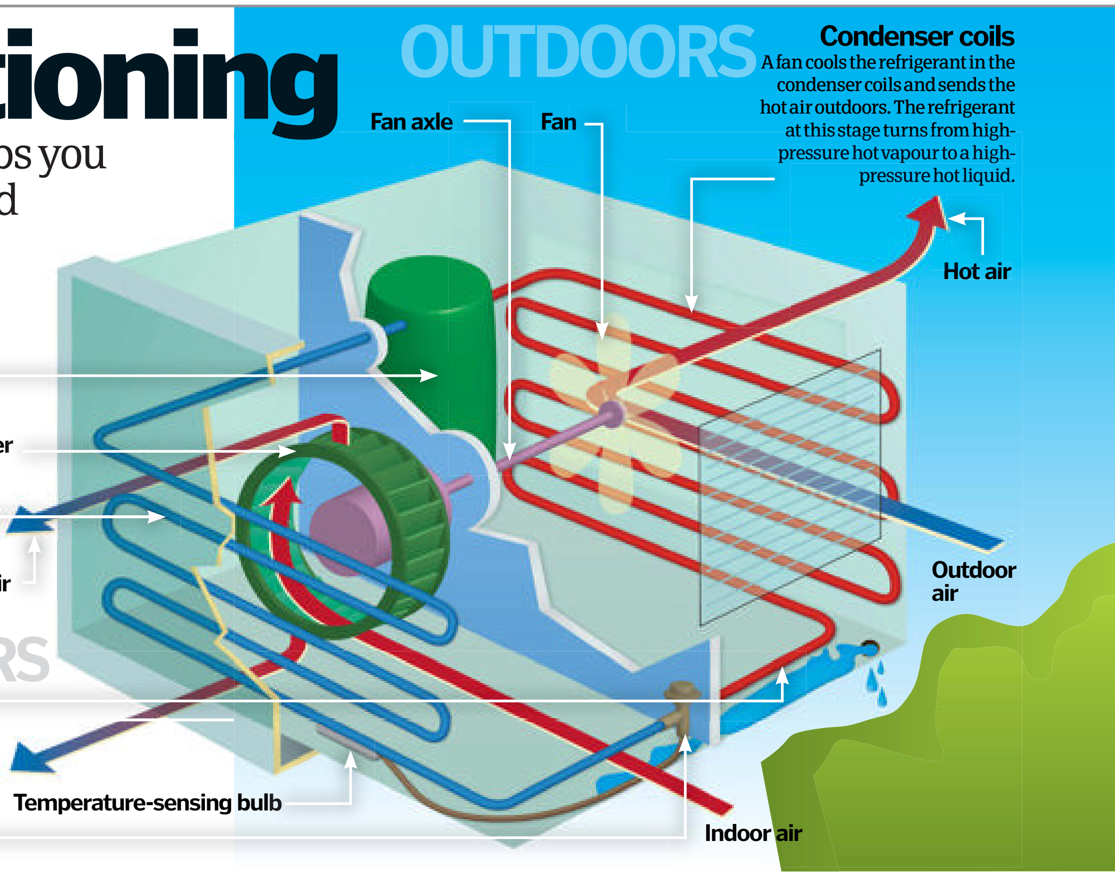
The technology that stops you getting hot and bothered

Compressor
Warm air drawn from the room by the blower turns the refrigerant in the cooling coils into low-pressure vapour. The compressor pressurises the vapour, turning it into high-pressure vapour that is sent to the condenser coils.

Cooling coils
Low-pressure cold liquid refrigerant (such as Freon developed by DuPont) runs through the cooling coils. The cold air produced by the coils is sent indoors by the blower.

Filter drier (not shown)
This may be fitted between the condenser coils and the expansion valve, or between the compressor and the cooling coils. It can hold the correct amount of refrigerant for the system to ensure its steady flow.

Expansion valve
This only allows a small amount of refrigerant to pass through it, turning the high-pressure hot liquid refrigerant into cold low-pressure liquid. It separates the high-pressure side of the system from the low-pressure side.



Condenser coils
A fan cools the refrigerant in the condenser coils and sends the hot air outdoors. The refrigerant at this stage turns from high-pressure hot vapour to a high-pressure hot liquid.

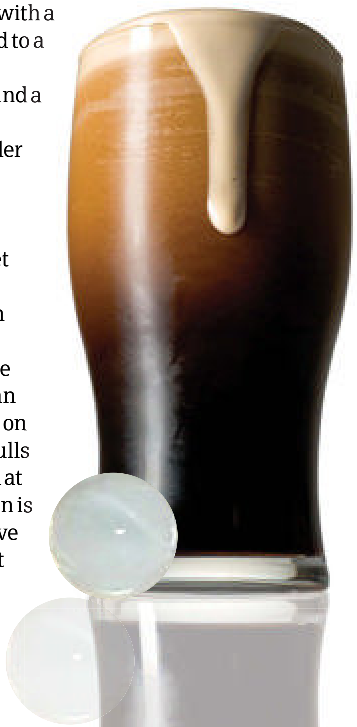
DID YOU KNOW?

It's not carbon dioxide that actually makes the bubbles in a drink, it's dirty glasses. CO2 is invisible, what you see is its silhouette outlined by trace elements.

Creating the perfect frothy beer head

Two pints of CO2 and a shot of liquid nitrogen

A widget is a small plastic ball with a hole in one end, which is added to a beer can. Beer is loaded with gaseous nitrogen and carbon dioxide, and a chaser of liquid nitrogen just before canning. When these elements are under pressure they're relatively inert, but remove the pressure – by pulling the ringpull – and they expand. If they evaporate in a thick liquid they don't get through as much of the liquid as they would in a thin one before they've been dissipated, because the speed of evaporation is constant but the distance they travel depends on how fast they can move. This movement creates the head on your beer. The nitrogen-filled widget pulls beer into it and shoves it back out again at high speed when the pressure of the can is released, exciting both elements to move through the liquid faster and aerating it with the evaporating gases.

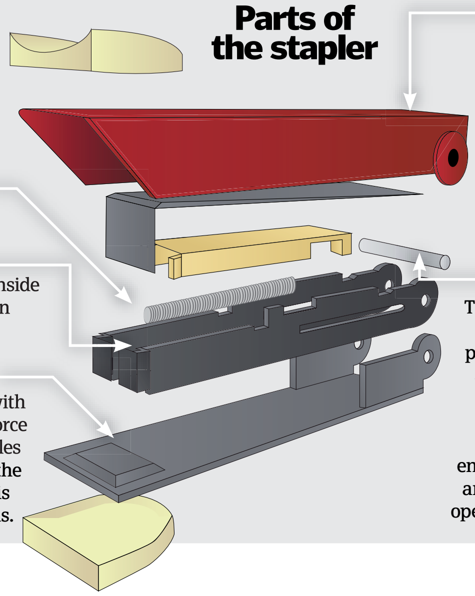


How staplers work

The gadget that attaches sheets of paper together easily and securely

The upper parts of the stapler mechanism pivot on a pin, secured to the base unit. Staples are placed facing downwards in the magazine cartridge and held in place by a spring. When the whole upper mechanism is pushed down onto sheets of paper, a metal plate forces the staple through the paper and into grooves on the base unit, where the downwards pressure forces the staple ends to bend.

Parts of the stapler



1. Head and arm
This contains the carriage and metal plate that pushes the staple downwards when pressure is applied.

2. Spring
The tension of the spring holds the staples in place and forces them forwards when a staple is used.

3. Magazine cartridge
Staples are placed inside the cartridge, held in place by the spring.

4. Pin
The upper part of the mechanism pivots on the pin, allowing it to be pushed downwards for stapling and enabling the head and arm to swing open for reloading.

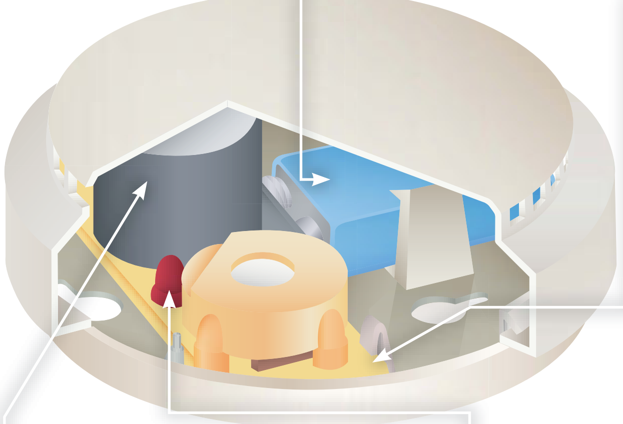
5. Base unit
Contains an anvil with grooves in it; they force the ends of the staples to bend over when the upper mechanism is pressed downwards.

Smoke alarms

How this radioactive domestic device saves lives

Most homes have them installed, but have you ever wondered how your smoke alarm actually detects the presence of smoke? The most common type of detector uses an ionisation chamber, which contains two plates (electrodes) separated by a small gap. Each electrode is connected to either the positive or negative battery terminal.

Between the electrodes is a tiny quantity of the radioactive element americium-241. This material emits alpha particles, which constantly smash into the chamber's air particles, splitting them into two – negatively charged electrons and positively charged ions. Polarity is always attracted to its opposite so, as the negative electrons and positive ions are attracted to the opposite electrodes. A small but steady electric current flows through the air, bridging the gap. The air effectively becomes a conductor. If smoke enters the gap, the smoke particles will disrupt this flow – it's the drop in electrical current that activates the alarm.



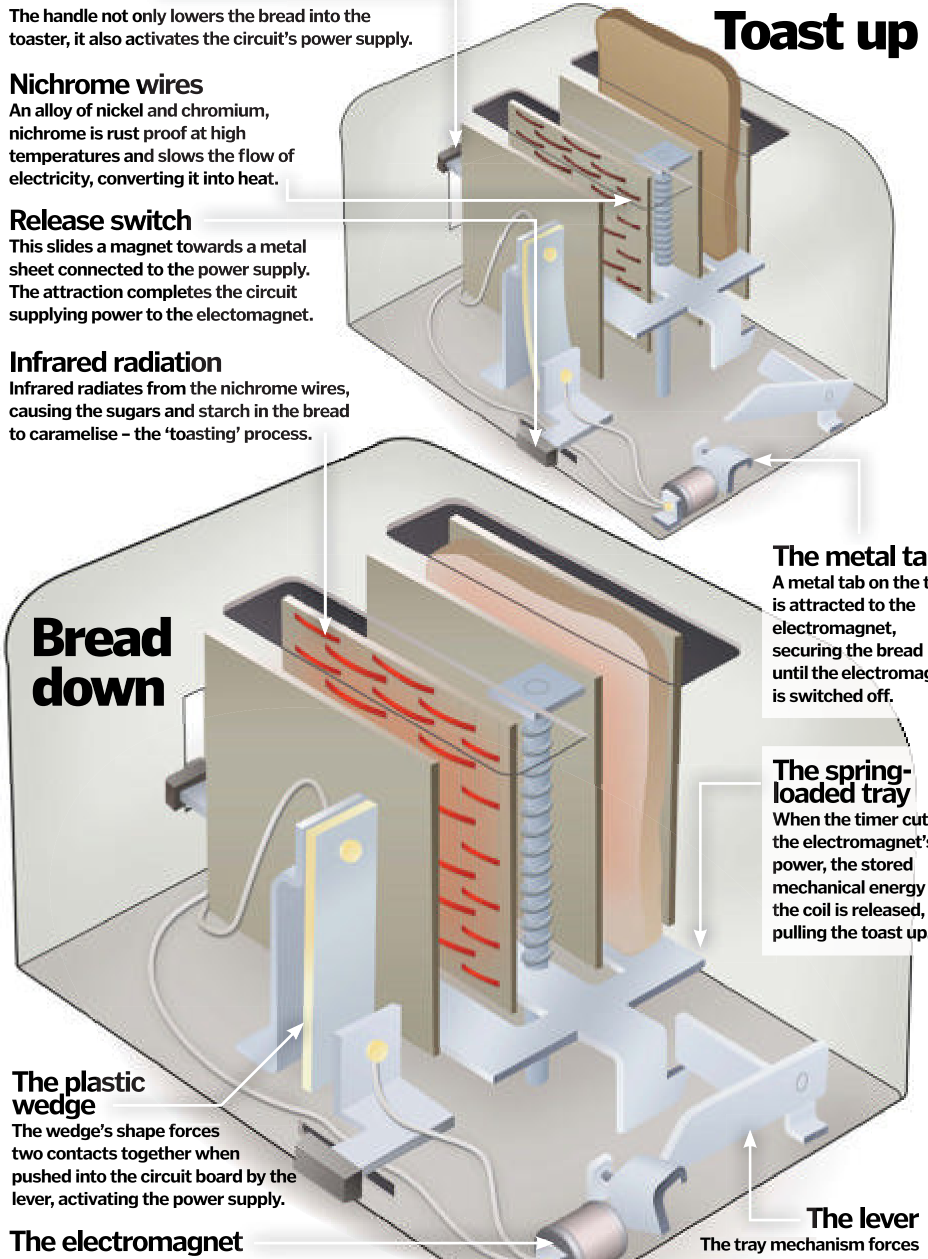
1. Battery terminals
The negative and positive terminals charge the plates (electrodes) inside the ionisation chamber with either a negative or positive polarity.

5. Printed circuit board
The circuit triggers the buzzer when the current drops below a certain level. It also activates a low power warning.

2. Ionisation chamber
Americium-241 ionises the air particles in the chamber. Air vents allow smoke particles to enter and neutralise the ions.

3. Mounting base
Brackets located on the mounting base allow easy fixing to ceilings and walls with common DIY tools.

4. Test button
The circuit board often features a test button, allowing the user to check the smoke alarm is functioning correctly.



The handle
The handle not only lowers the bread into the toaster, it also activates the circuit's power supply.

Nichrome wires
An alloy of nickel and chromium, nichrome is rust proof at high temperatures and slows the flow of electricity, converting it into heat.

Release switch
This slides a magnet towards a metal sheet connected to the power supply. The attraction completes the circuit supplying power to the electomagnet.

Infrared radiation
Infrared radiates from the nichrome wires, causing the sugars and starch in the bread to caramelise – the 'toasting' process.

The metal tab
A metal tab on the tray is attracted to the electromagnet, securing the bread until the electromagnet is switched off.

The spring-loaded tray
When the timer cuts the electromagnet's power, the stored mechanical energy in the coil is released, pulling the toast up.

The plastic wedge
The wedge's shape forces two contacts together when pushed into the circuit board by the lever, activating the power supply.

The electromagnet
When supplied with electric current, the electromagnet attracts the metal tab on the tray, holding it down.

The lever
The tray mechanism forces the lever to close. This becomes secured under the metal tab, holding the bread and tray inside.

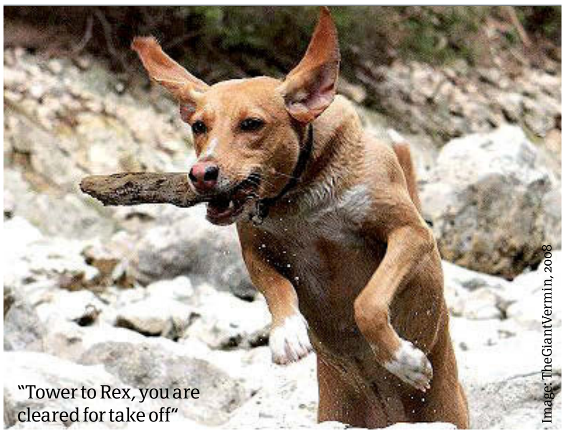
Toasters

What transforms a slice of bread into tasty toast?

When the handle lowers the bread, a wedge forces two contacts together which connects the power supply to nichrome wires wrapped around plates called mica sheets. Nichrome is a highly resistant material that converts electrical current into heat. The spring-loaded tray forces a lever down which snaps into place under a metal tab, holding the bread inside. Sliding the release switch moves a magnetic element towards a metal sheet connected to the power supply. Once they make contact the completed circuit activates the electromagnet, attracting the metal tab towards it. The lever is released, allowing the tray mechanism to spring back up. And out pops that toast!

The chips are only slightly larger than a grain of rice

Image: courtesy of Destron Fearing



"Tower to Rex, you are cleared for take off"

Image: TheGiantVermin, 2008

Pet ID chips explained

If Lassie had one of these she'd have come home a lot sooner…

When a cherished pet goes missing, any caring owner will do all they can to get their beloved animal back. One increasingly popular way of improving your chances of seeing old Fido again is getting him chipped – that is, having a tiny microchip implanted under the skin between the shoulder blades.

The chip is programmed with a unique identifying number that refers to the owner's details stored in a nationwide database. This ID number will permanently identify the pet and its owner. So, should a chipped pet end up at an animal rescue shelter, it will be scanned revealing the unique number.

ID chips use passive (ie no power source) radio frequency identification (RFID) technology. They consist of a silicon chip, containing the identification number and a circuit that relays information to the scanner; a coil inductor (or radio antenna) to receive the signal from the scanner; and a capacitator, which, together with the inductor, picks up the signal from the scanner. ✲

In the spin

How do washing machines clean our clothes?

Most homes are lucky enough to have one, but have you ever wondered how a washing machine works? After separating your laundry into whites and colours – so as to protect your whites from colour run – load your clothes into the main drum and close the door. Once you've programmed the machine to tell it what sort of wash you require – temperature, speed, length and so on – the machine then adds water and detergent and sloshes the clothes around. After a time, the drum will spin really fast – up to 130km/h (80mph) – creating a centrifugal force that extracts most of the water out of the clothes and out through the holes in the inner drum where it is then pumped away. ✲

2. Detergent

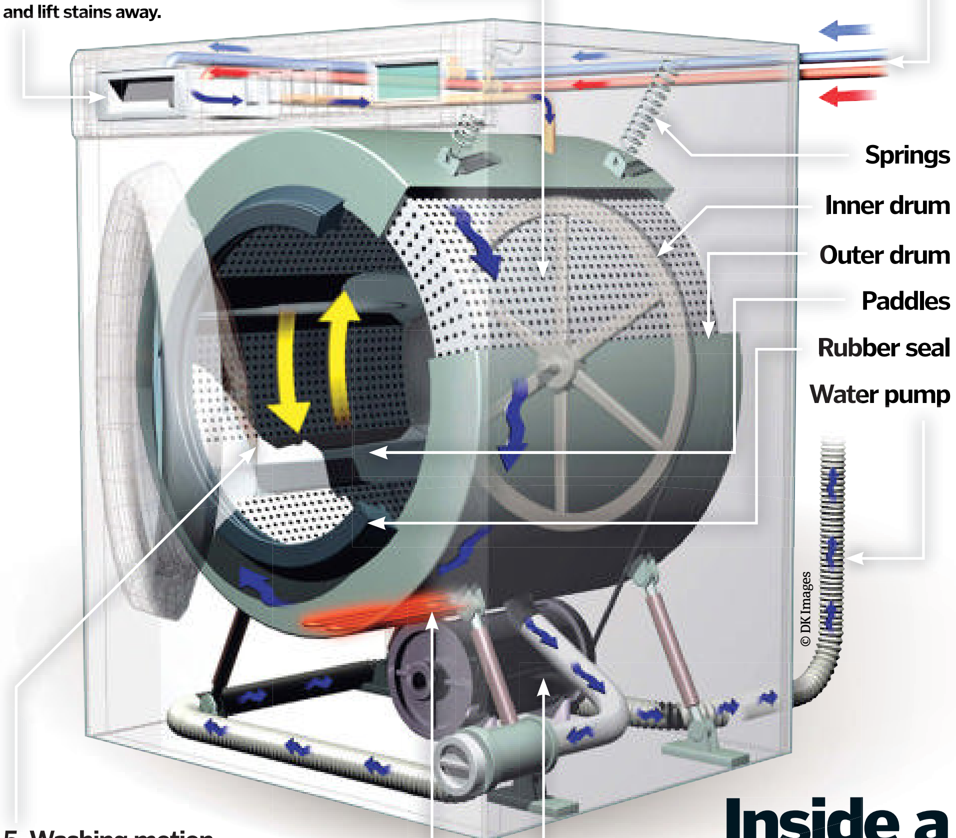
The water washes through a tray containing detergent. Laundry detergent contains surfactant molecules, which are attracted to water, reducing the water's surface tension. This allows the soap to better penetrate the clothes and lift stains away.

6. Centrifugal rinsing

A pump then extracts the dirty water, and the clothes are then rinsed. The drum then spins up to 1,400 times per minute, extracting as much water from the load as possible before the cycle finishes.

1. Water inlet

Water enters the machine via inlet pipes. Modern machines endeavour to use as little water as possible in order to be environmentally friendly. Some models even have the capacity to weigh the load to assess how much water is required.



© DK Images

Inside a washing machine

5. Washing motion

The cyclical motion of the spinning drum ensures the clothes get good and soapy, and paddles around the sides of the drum scoop up the soapy water and distribute it all over the clothes. The spinning creates a lot of vibration, which can be partly absorbed by the springs located between the main drum and the outer structure.

3. Heating element

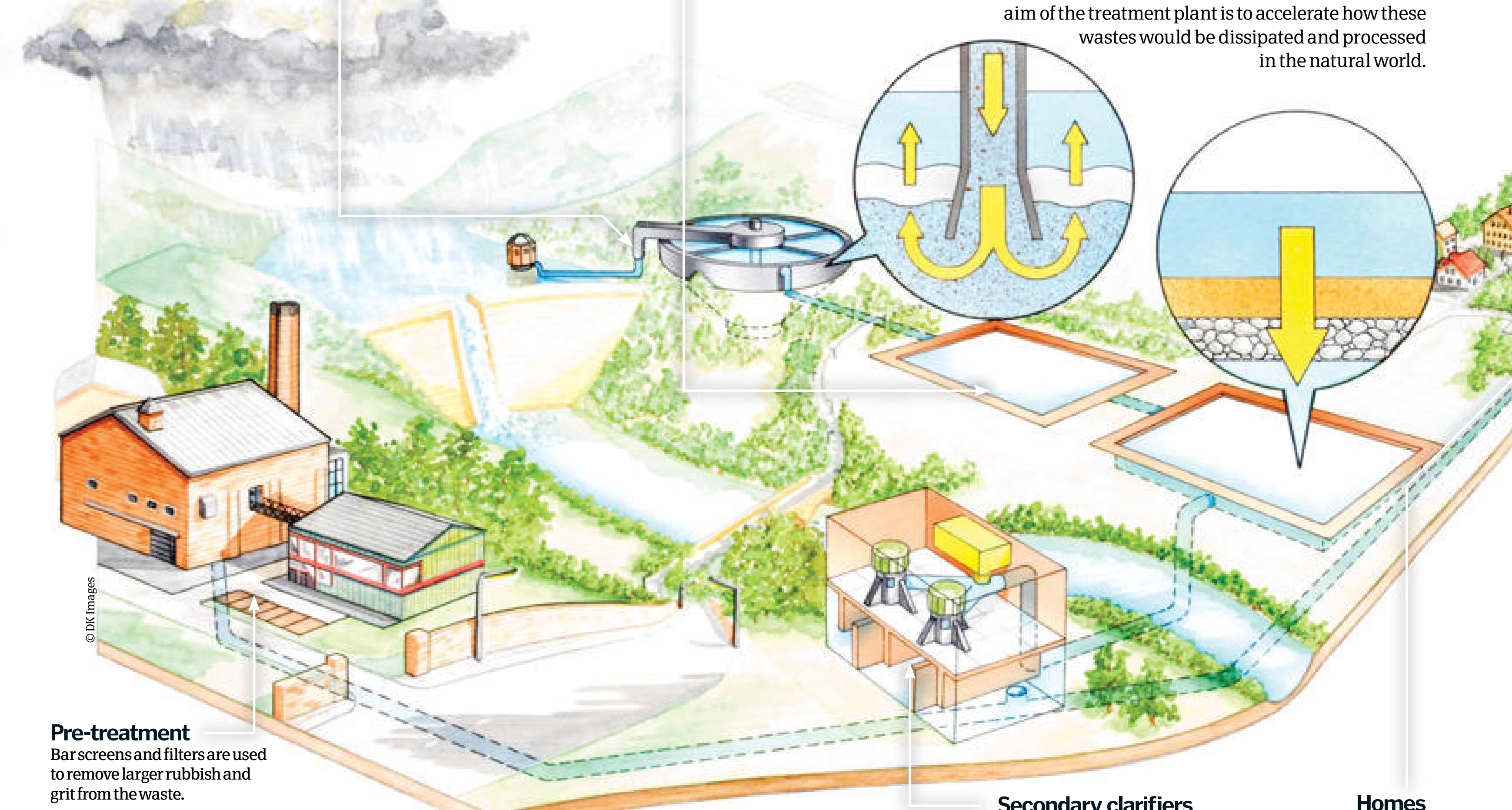
The soapy water then drains into the outer drum and through tiny holes down the sides of the inner drum where it collects at the bottom. Here the water is heated by a heating element. As less water is used in modern machines, less electricity is needed to heat it.

4. Motor

Once the water is the right temperature – as indicated by the program selected – a motor then drives the inner drum round inside the larger outer drum. The motor is attached to a large wheel at the back of the machine.

A sewage treatment plant

The treatment of sewage consists of pre-treatment, primary and secondary processes. The aim of the treatment plant is to accelerate how these wastes would be dissipated and processed in the natural world.



Primary clarifier
Solids settle to the bottom of the tank, while the remaining liquid waste is sent to the aeration tanks.

Aeration tanks
Air pumped into the tanks promotes the growth of micro-organisms that feed on the remaining organic matter in the waste.

Pre-treatment
Bar screens and filters are used to remove larger rubbish and grit from the waste.

Secondary clarifiers
90% of the solids and micro-organisms are removed from the waste.

Homes
Sewage is flushed from homes and sent for treatment.

© DK Images

Sewage treatment

How our waste products are processed to provide pure water and prevent the spread of fatal diseases

When you go to the toilet and flush away your waste, how is it treated to stop it polluting our environment? Until the 19th Century, no one cared where it went, but with the growth of towns and cities, human waste became a problem.

Besides toilet paper and other solid material sent down the loo, solid human waste contains harmful bacteria that can easily spread disease, as well as phosphates and nitrogens that encourage the growth of algae when it is released into bodies of water. The algae fouls waterways and blocks light, thereby preventing the ability for fish and other creatures to see or breathe properly. The waste also reduces the oxygen in water due to the decomposition of bacteria. This, along with its dirty colour and the stink it causes due to the release of hydrogen sulphide gas caused by its nitrogen-rich bacteria, all make our waste highly unpleasant and deadly to our environment and ourselves.

The solution in the developed world was to link the new flushing toilets to vast underground sewage systems, to take the waste away from the towns to rivers or the sea. This just moved the problem away from the towns, but in the 20th Century sewage treatment plants were developed and improved. These treatment plants separate the solids from the liquids, and the waste that cannot be processed and recycled is sent to landfill or incineration.

Strict laws and regulations in the developed world control where and how treatment plants discharge waste, but in many countries sewage is still released without any type of treatment.

5 TOP FACTS SEWAGE

The great stink

1 The introduction of flushing loos in London caused a pong in 1858. The extra water flowing into the city's 200,000 cesspits caused untreated sewage to pour into the streets.

Purity

2 80% of countries have low standards of water purity, and in the developing world especially one in six people still don't have access to clean drinking water.

The state of China

3 While the number of Chinese sewage treatment plants is steadily increasing, 55% of China's sewage is still not treated. There are only around 2,000 plants in the country.

Explosive manholes

4 In American cities there have been reports of manhole covers exploding into the air. This is likely due to heat from electrical cables, gases and the odd stray spark underground.

New York

5 New York City has 14 sewage treatment plants that deal with 1.4 billion tons of waste a day. The average person in the US produces 14kg of solid waste a week.

DID YOU KNOW? *In the USA, 40,000 sanitary sewer overflow (SSO) events happen every year*

Typical sewage treatment systems

1. Overflow

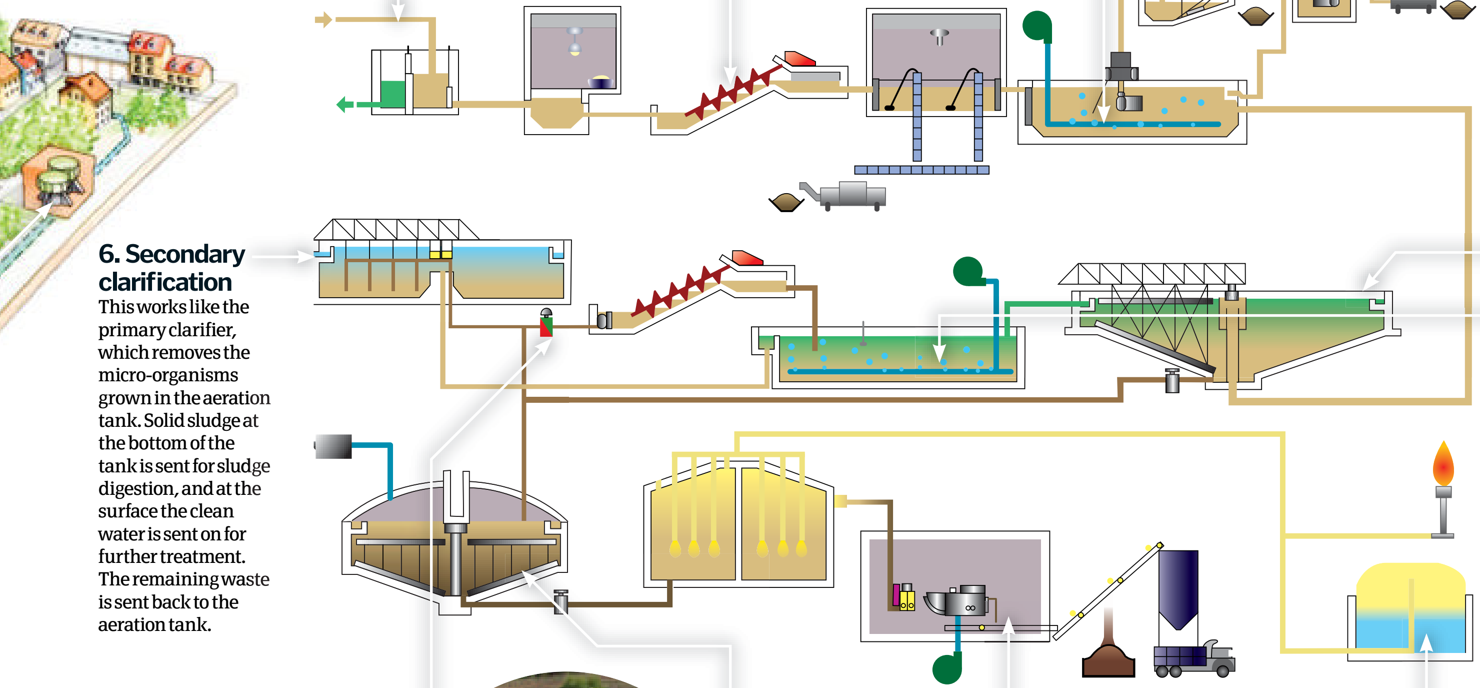
An excess of rainwater entering the sewer system can overwhelm sewage plants. Various methods are used to drain it away without treatment, or to store it in retention basins or huge concrete tanks. It can then be filtered and sent for further treatment.

2. Solids

Bar grids and screens are used to remove solid items of rubbish that can include leaves and litter. Smaller screens are used in chambers where grit and sand can be allowed to sink to the bottom and removed. These solids are either incinerated or sent to landfill.

3. Fat and grease

To remove these products, air is pumped into a chamber where the fat and grease rise to the surface. Pumps take this fatty scum away to tanks where it is collected and removed.



4. Primary clarification

These tanks allow any fat, grease or oil to rise and for sludge to settle at the bottom. Scrapers send the primary sludge downwards, where it's collected and pumped for further processing.

5. Aeration

Air is pumped into this tank to encourage the growth of aerobic micro-organisms. They feed on the organic matter that remains in the waste from the primary clarifier.

6. Secondary clarification

This works like the primary clarifier, which removes the micro-organisms grown in the aeration tank. Solid sludge at the bottom of the tank is sent for sludge digestion, and at the surface the clean water is sent on for further treatment. The remaining waste is sent back to the aeration tank.

SAMPLING POINT

7. Disinfection

The water from aeration still needs to be purged of hazardous micro-organisms. Chlorine has been a common chemical used to disinfect water, but it can produce residues that are harmful to aquatic life and may be carcinogenic. The water therefore has to be dechlorinated. An alternative is to subject the water to ultraviolet light, or to use ozone instead of chlorine.

8. Sludge digestion

The sludge consists of water and oxygen-hungry, foul-smelling organic matter. Inside the enclosed tank, anaerobic bacteria that lives without oxygen makes the sludge inert. It is a slow process that can be speeded up by heating the tank between 25°C and 40°C.

9. Drying and sludge finishing

The inert sludge can be dried and dewatered in a separate chamber, and sent for incineration or landfill. In both cases, precautions have to be made to prevent pollution of the environment by this material. To kill the pathogens in dewatered sludge, hydrated lime $Ca(OH)_2$ or quicklime CaO is added to it to produce bio solid fertiliser.

10. Gasses

When sludge is being digested and dried it produces a mixture of gasses, which mainly consist of up to 70% methane and 30% carbon dioxide, along with a small amount of nitrogen and hydrogen. These gasses can be collected and used to heat the sludge or power the plant.

Waterborne diseases

Waterborne diseases are spread by damaged or non-existent sewer systems, pollution and natural disasters. They tend to be caused when animal and human urine or faeces gets into the water supply and encourage the proliferation of deadly viruses and bacteria.

Diarrhoea is a common symptom of waterborne disease. Every day at least 5,000 children die of diarrhoea-related diseases due to bad sanitation. Diarrhoea exhibits itself as frequent evacuation of watery faeces and can last several days. Cholera bacterium in untreated water causes severe vomiting and diarrhoea, leading to dehydration and life-threatening consequences. If diarrhoea-infected faeces should enter the water supply, it helps to spread the disease even further in the population.

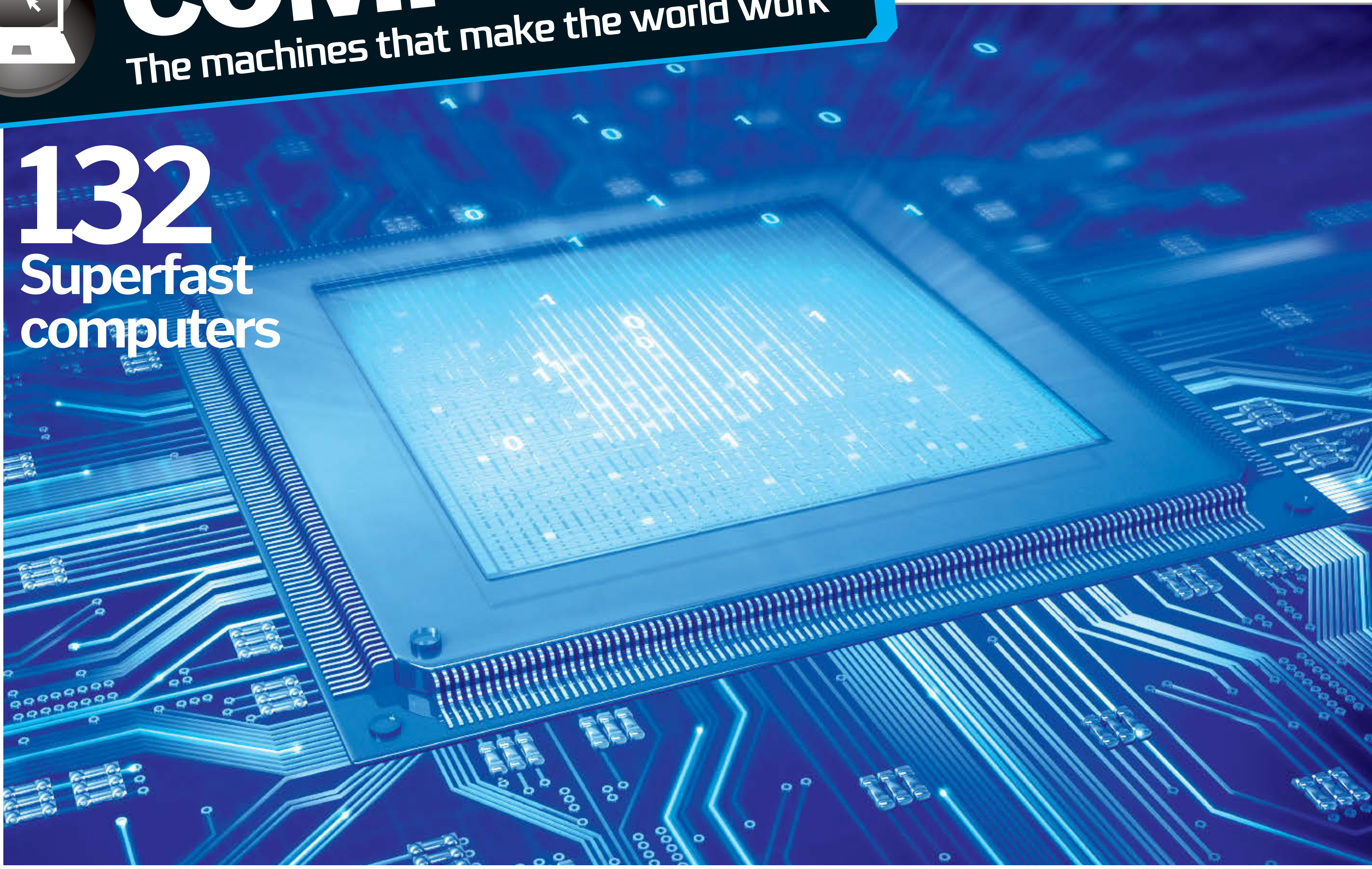
Arsenic in water supplies can cause cancer of the kidney, lungs, bladder or skin. For example, in Bangladesh the World Health Organization estimates that 77 million people are exposed to high levels of arsenic in groundwater, which is the main source of fresh water.

Unsanitary water, food and hygiene standards can also cause hepatitis A and C. This causes an inflammation of the liver and is highly contagious.

HOW IT WORKS

COMPUTING

The machines that make the world work



132 Superfast computers

112 **Spotify** Bringing music to the masses for free

114 **Superfast broadband** A world of knowledge at your fingertips

118 **QR codes** The barcode that's readable by smartphones

118 **Electronic ink** Never get it on your shirt pocket again!

119 **Firewalls** Keeping your computer safe from viruses

119 **IBM Roadrunner** How does this amazing supercomputer work?

120 **MacBook Pros** Apple's awesome laptop explained

122 **Wi-Fi** Understanding this everyday tech

122 **USB drives** The handy way to save and transfer work

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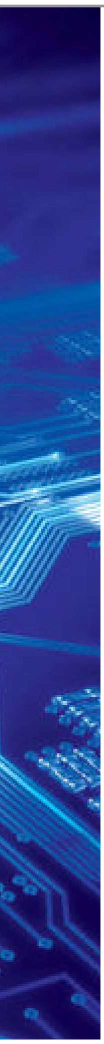
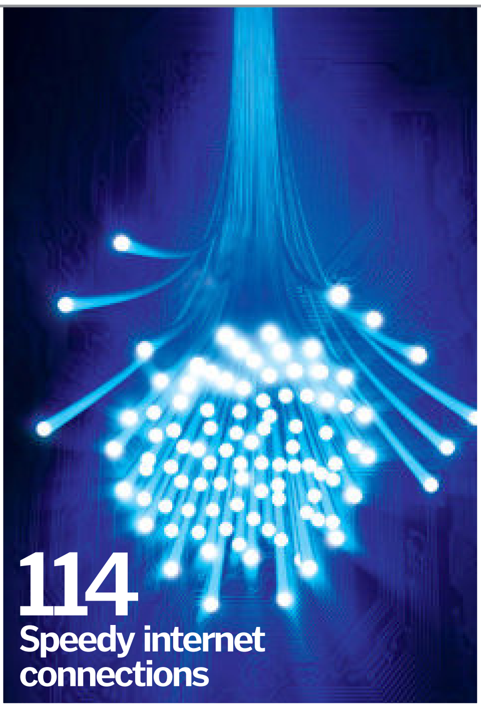
HOW IT WORKS

COMPUTING



138 The world of social networks



114 Speedy internet connections

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The next-generation of data storage explained

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Processing information at incredible speeds

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The place to go if you want your own website

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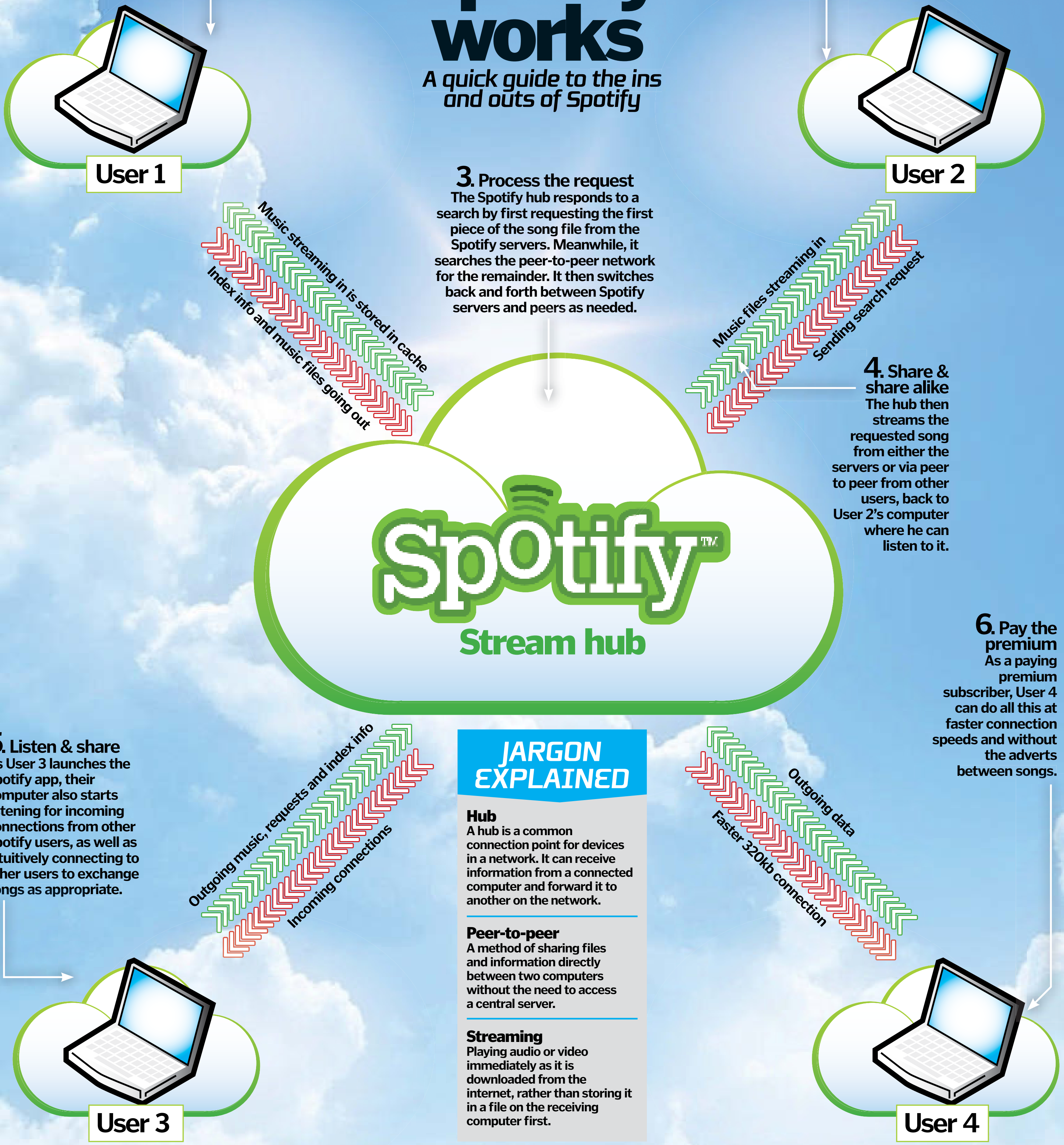
The technology behind the hottest trends, including Facebook and Twitter

Personal Firewall

119 Implementing firewalls

How Spotify works

A quick guide to the ins and outs of Spotify


User 1
User 2
User 3
User 4
Spotify™
Stream hub
Music streaming in is stored in cache
Index info and music files going out
Music files streaming in
Sending search request
Outgoing music, requests and index info
Incoming connections
Outgoing data
Faster 320kb connection

1. Log in and share

As User 1 logs on, the contents of their Spotify cache are indexed and sent to the Spotify streaming hub when they connect to the service. Music files are stored to their cache as they play them.

2. Search for music

User 2 performs a search for a song or artist. This request is then processed by the hub against the index that it compiles from all users.

3. Process the request

The Spotify hub responds to a search by first requesting the first piece of the song file from the Spotify servers. Meanwhile, it searches the peer-to-peer network for the remainder. It then switches back and forth between Spotify servers and peers as needed.

4. Share & share alike

The hub then streams the requested song from either the servers or via peer to peer from other users, back to User 2's computer where he can listen to it.

5. Listen & share

As User 3 launches the Spotify app, their computer also starts listening for incoming connections from other Spotify users, as well as intuitively connecting to other users to exchange songs as appropriate.

6. Pay the premium

As a paying premium subscriber, User 4 can do all this at faster connection speeds and without the adverts between songs.

JARGON EXPLAINED

Hub
A hub is a common connection point for devices in a network. It can receive information from a connected computer and forward it to another on the network.

Peer-to-peer
A method of sharing files and information directly between two computers without the need to access a central server.

Streaming
Playing audio or video immediately as it is downloaded from the internet, rather than storing it in a file on the receiving computer first.

NEWEST

1. Spotify
The pairing of a minimal UI and instant musical gratification, thanks to audio being streamed instead of downloaded, makes Spotify a real contender for the crown.

BIGGEST

2. iTunes
With no monthly subscription, the best UI on the net, fantastic pairing with iPhones and iPods, as well as the ability to buy single tracks, iTunes is rightly the market leader.

MOST CUSTOMISABLE

3. Last.fm
Last.fm is a popular internet radio and music service which uses a music recommender system call 'Audioscrobbler' to custom build a profile for each of its users.

DID YOU KNOW? *Spotify has been active in various European countries since October 2008*

What is Spotify?

Seen by many to be the next stage in the evolution of music distribution and reproduction, Spotify is bringing music to the world of cloud computing

Spotify is a new application that is available for PC and Mac – along with many modern smartphones – which allows you to stream music from a vast catalogue distributed through the Spotify central hub and sourced from every other Spotify user.

To use Spotify you would first need to download the Spotify software from **www.spotify.com**. Once installed, Spotify looks a lot like other media players such as iTunes, but there is a big difference. With Spotify, you don't have to download the music in order to listen to it (although this is also possible). Instead you can simply stream it over your internet connection.

How does this work? Well, Spotify delivers music to your PC using a combination of peer-to-peer sharing and streaming from its servers (see the jargon boxout on the previous page for an explanation of these terms). When a Spotify user opens the application it makes an index of the contents of their Spotify cache and sends this to the Spotify streaming hub. The cache contains all the music files or pieces of music files that Spotify sends when a user is listening to tracks. The streaming hub can then use this index to share these music files and pieces of files with other Spotify users. So while you are receiving the music stream, your computer is also sending music to other users on the network and it's this combination of peer-to-peer sharing and streaming from a server that gives Spotify its famously fast response time.

In other respects, Spotify works like many other media players and online music stores, allowing users to browse its 6 million tracks via name, genre, artist and so on, as well as allowing custom playlists to be created and random radio lists to be constructed. Individual tracks, albums, playlists, as well as money to extend subscriptions or buy downloads, can also be shared easily from user to user and there are community forums in order for users to stay in touch with each other.

Spotify makes money through both interspersing music tracks with advertisements (the frequency of these adverts can vary depending upon time-frames, and can last between 10 and 30 seconds), or by getting its users to sign up as a premium user, which costs £9.99 per month. If the user takes up a premium subscription then there are no advertisements between tracks, allowing for continuous playback.

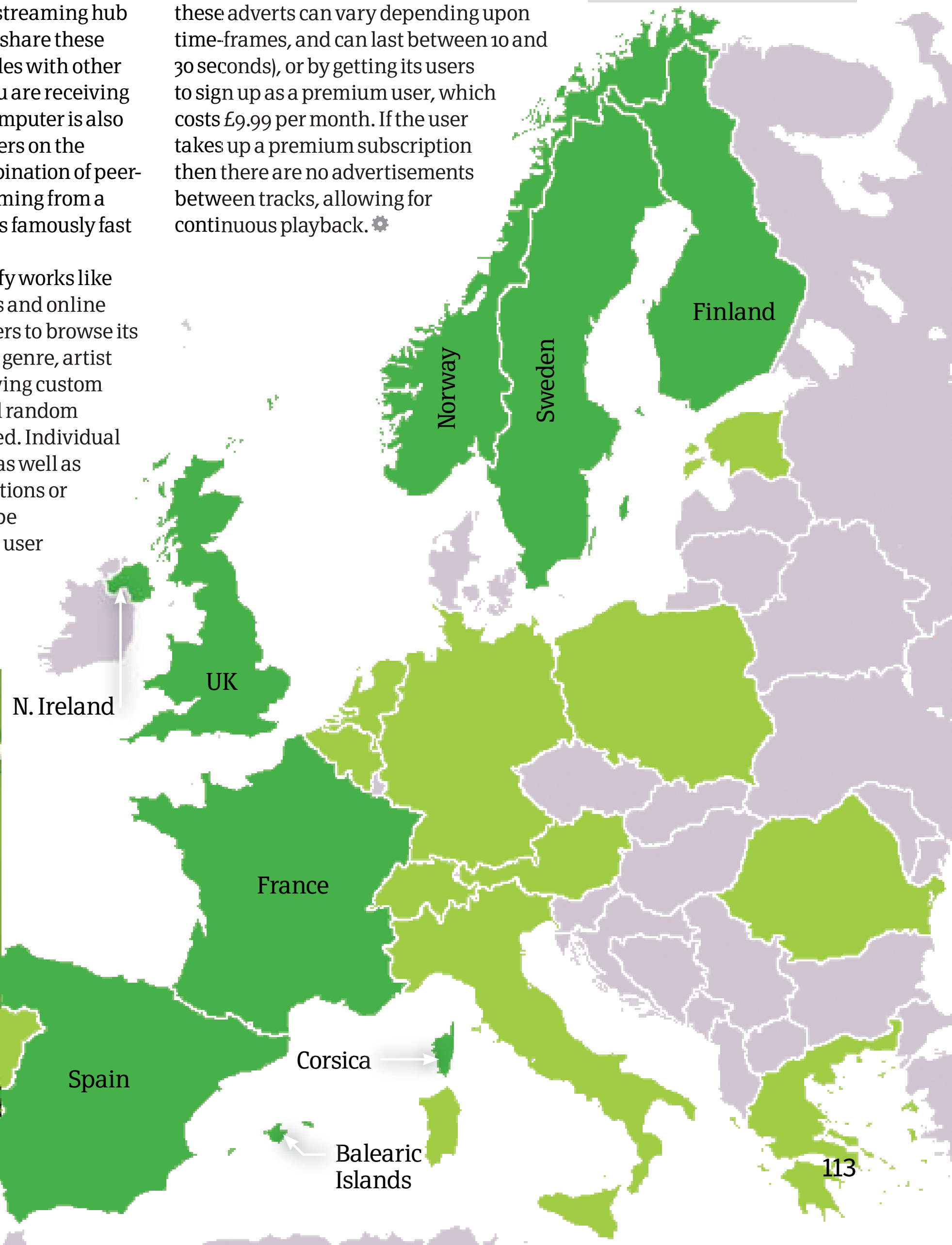
Cofounders of Spotify Daniel Ek and Martin Lorentzon

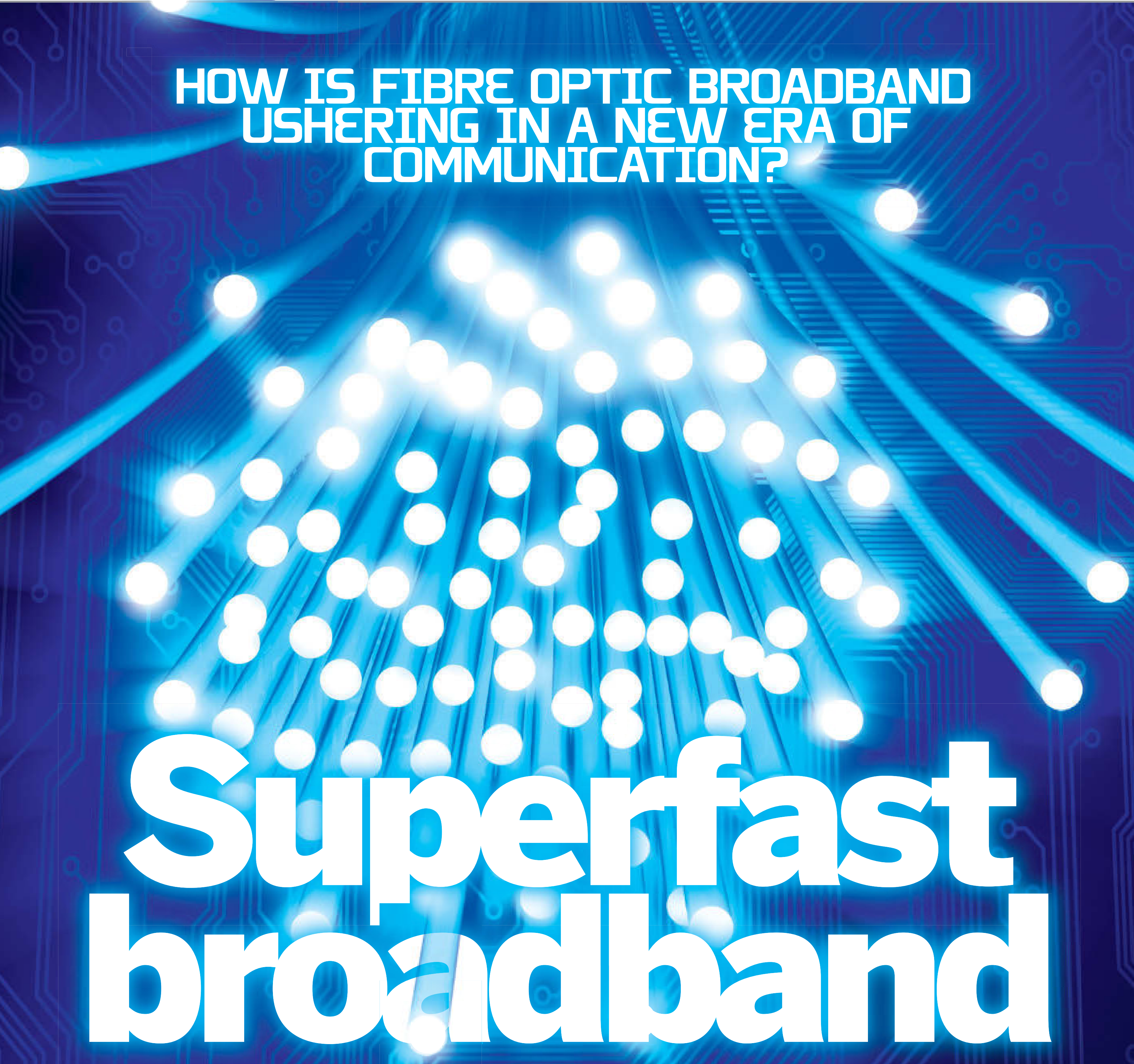
ON THE MAP

Where is Spotify available?

Currently it can be used in:
- **United Kingdom**
- **France**
- **Sweden**
- **Spain**
- **Norway**
- **Finland**
- **Netherlands**

It will also be available in:
- **Italy**
- **Portugal**
- **Germany**
- **Denmark**
- **Estonia**
- **Poland**
- **Belgium**
- **Austria**
- **Switzerland**
- **Romania**
- **Greece**





Superfast broadband

HOW IS FIBRE OPTIC BROADBAND USHERING IN A NEW ERA OF COMMUNICATION?

Remember dial-up internet? Most of us do and it's not so very long ago that speeds of 56K were considered fast when it came to accessing the delights of the world wide web. And while it may have been fine for checking GeoCities pages and bulletin boards, as our demands and uses of the internet became more complex so higher speeds became more necessary, can you imagine using iTunes or YouTube on a 56K modem? Neither could the service providers who now vie for our attention, trying to find the balance between faster connections and lower prices.

Currently the fastest speed on offer in the UK and US and most of Europe lie somewhere between 2MB and 10MB while China, South Korea and Japan lead the way in 'fibre-to-the-home' broadband lines. However many western nations such as America, Sweden and Romania are following close behind. Over the next few pages we'll be explaining fibre optics, the amazing technology behind the new generation of internet connections, so read on to find out just how it works, where you can find it and why some countries are faster than others. ✿

5 TOP FACTS INTERNET

WWW

1 The man credited with inventing the internet is Sir Tim Berners-Lee, a British computer scientist and professor at the Massachusetts Institute of Technology.

Dominant

2 The prevalent language of communication on the internet is English, followed by Chinese and Spanish. This is despite 42 per cent of total users being based in Asia.

Modal

3 Currently, in the UK the fastest commercial fibre optic line broadband connection is an 'up to 50MB' connection. The lines are available in selected areas only.

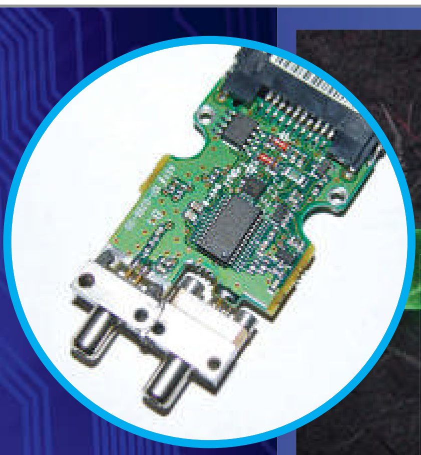
VIP

4 The first switched telephone network arrived in Britain in 1879 when The Telephone Company Ltd opened its first exchange in London. It served just eight subscribers.

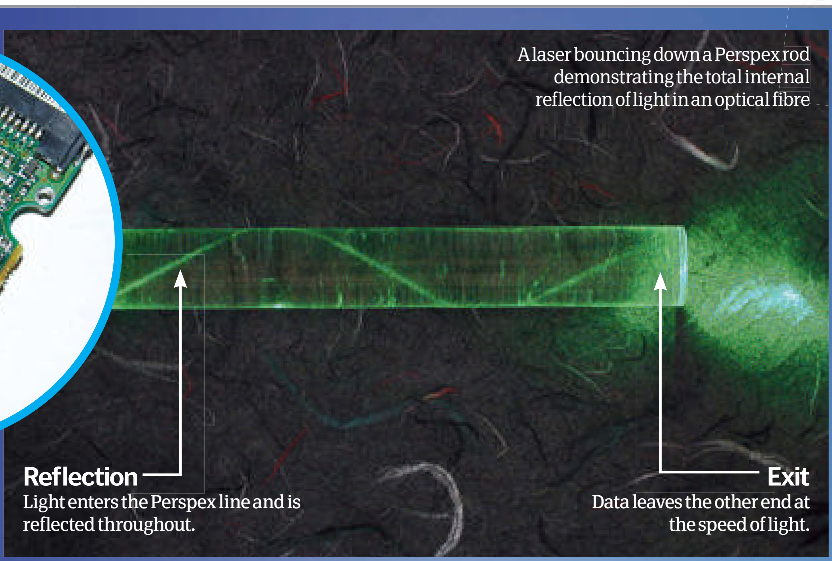
Victorian

5 Many copper-based communication lines in the UK can trace their origins back to Victorian and Edwardian times, especially in built-up areas around major cities.

DID YOU KNOW? *Currently all new undersea cables are made of optical fibres*



A standard transceiver used to send and receive data



A laser bouncing down a Perspex rod demonstrating the total internal reflection of light in an optical fibre

Reflection
Light enters the Perspex line and is reflected throughout.

Exit
Data leaves the other end at the speed of light.

Superfast broadband explained

The brand new breed of superfast broadband connections is made possible by switching from copper telephone wires to new fibre optic cables. Fibre optic broadband essentially works by transmitting data as pulses of light from an exchange throughout an optical fibre – a cable consisting of a light-carrying glass core, light-reflecting cladding (to ensure total light retention) and protective buffer coating – before then receiving and decoding that information at the far end with a transceiver.

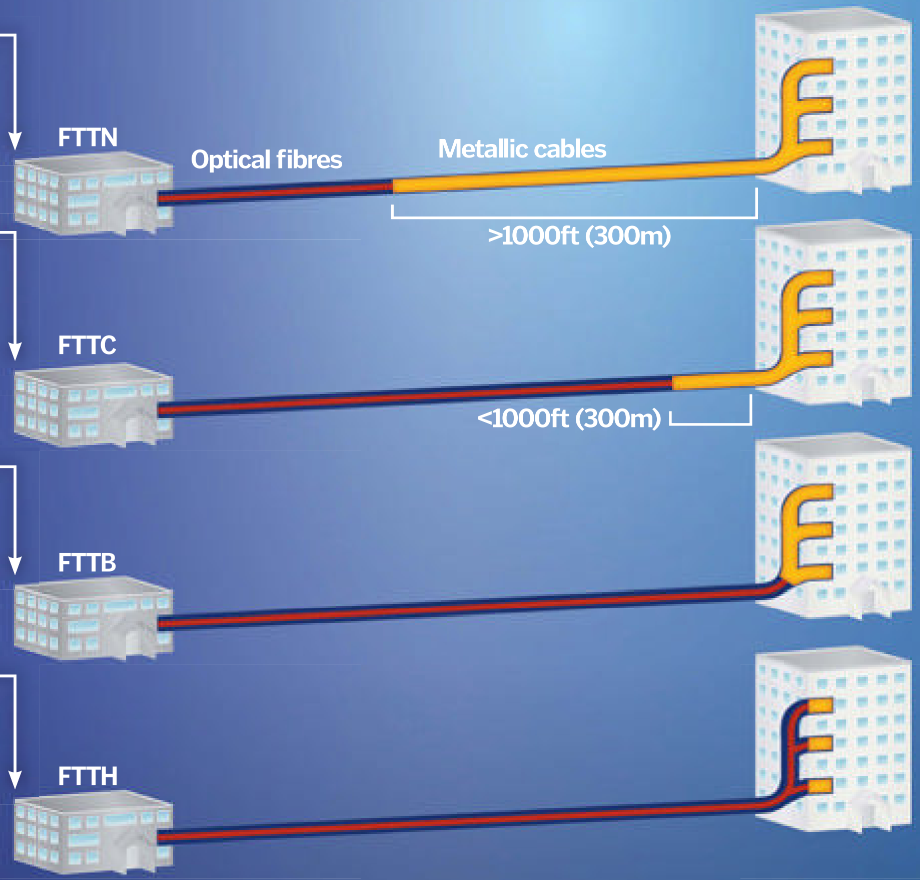
A fibre optic line is an excellent medium for communication purposes as it holds numerous advantageous properties over the existing copper-based wiring networks. Most notable is its long-distance data delivery speed, a factor made possible because light propagates through fibre with little attenuation and, obviously, at the speed of light. Further, each fibre optic cable can carry many independent channels of information, each using a different wavelength of light, so the sheer amount of data is increased also.

Broadband now

In most countries, broadband is delivered down copper telephone wire, which suffers from speed, range and breadth restrictions. The wire, which is prevalent across most networks, often dates from the early 20th or even late 19th Century and carries information through electric pulses. This is problematic in terms of maintaining speed at long ranges as all electrical transmissions are subject to high electrical resistance, and information effectiveness is compromised. In addition, electrical transmission lines suffer when tightly packed from crosstalk – a phenomenon by which a signal transmitted on one circuit or channel of a transmission system creates an undesired effect in another circuit or channel. In short, the system is an ageing one, unable to meet today's demands.

Delivery

A diagram illustrating how broadband architectures vary depending on the distance between the optical fibre end-point, existing copper-based network and the user. The building on the left is the communications exchange; that on the right is representative of one of the buildings served by it.



FTTN
(Fibre-to-the-node)
Optical fibre is terminated at a node multiple miles from the user's residence, with the connection from it to the premises being copper-based.

FTTC
(Fibre-to-the-cabinet)
Similar to FTTN, this configuration sees any optical fibre terminated at a street cabinet closer to the user's house. The connection from it, though, is still copper.

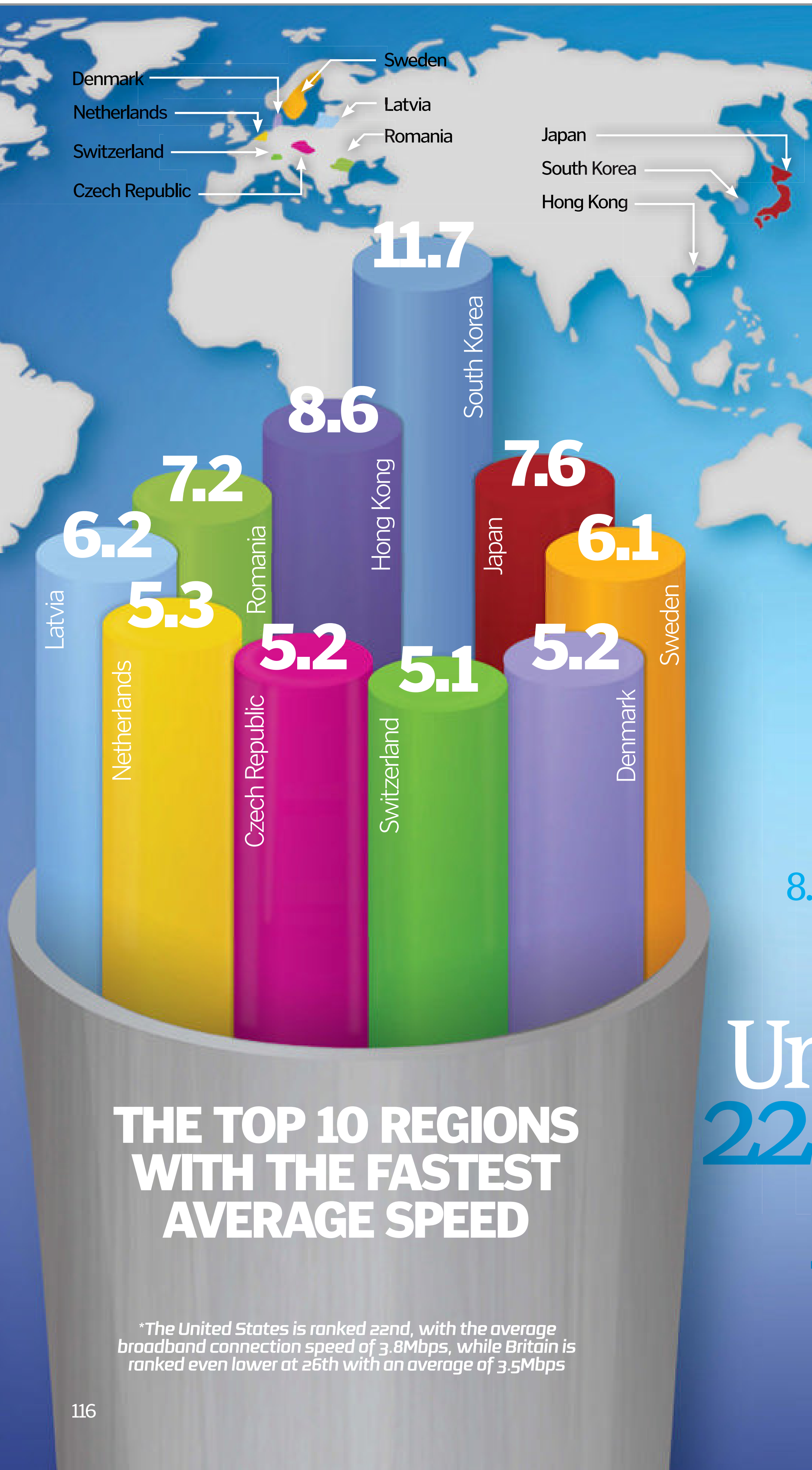
FTTB
(Fibre-to-the-building)
Used in apartment and office blocks, this sees the optical cable stop at the boundary of the structure, the final connection being delivered by other means.

FTTH
(Fibre-to-the-home)
Here an optical fibre line enters the user's premises like a regular copper connection. No copper connections are necessary in the 'last mile' and speed is vastly increased.

The last mile

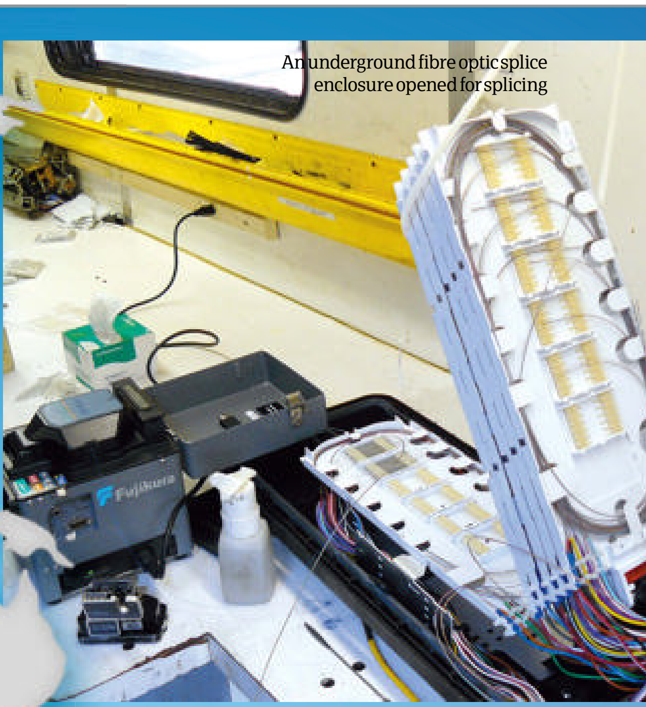
The term 'the last mile' refers to the final leg of delivering broadband communications from a provider to a user. In reality, the last mile may in fact be considerably further than a mile, with many miles separating the two. This is because at this late stage any main cable must be fanned out and split to service numerous separate clients, often living far apart. This is time-consuming and carries a large expense. However, if the 'last mile' is too great a distance, then the cable infrastructure is rendered useless as it cannot sustain information flow due to speed loss.

To address these connectivity issues many operators share and splice networks to reach customers, with cabling varying in type and length depending on where the user is based. This has the obvious drawback that while initially a line from a provider may be fibre optic (carrying data faster and further with less speed loss), at the users' end, in the 'last mile', it may be fanned out onto an old, pre-existing copper line, which, as we've mentioned, sustains high-speeds poorly, especially over large distances.



THE TOP 10 REGIONS WITH THE FASTEST AVERAGE SPEED

**The United States is ranked 22nd, with the average broadband connection speed of 3.8Mbps, while Britain is ranked even lower at 26th with an average of 3.5Mbps*


An underground fibre optic splice enclosure opened for splicing

1. South Korea – 11.7 Mbps
2. Hong Kong – 8.6 Mbps
3. Japan – 7.6 Mbps
4. Romania – 7.2 Mbps
5. Latvia – 6.2 Mbps
6. Sweden – 6.1 Mbps
7. Netherlands – 5.3 Mbps
8. Czech Republic – 5.2 Mbps
9. Denmark – 5.2 Mbps
10. Switzerland – 5.1 Mbps

22 United States of America

26 Great Britain

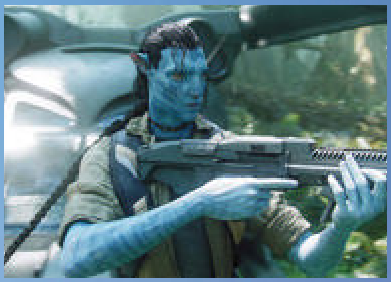
DID YOU KNOW? *The government of Estonia passed a law declaring internet access a fundamental human right of its citizenry*

© Dhaluza

Why are some countries faster than others?

If you've been looking at the speeds on offer in Asian countries and experiencing an extreme case of broadband envy then you might be wondering just why the services on offer in South Korea, Hong Kong and even Sweden are better than those in the US or UK. Part of the answer lies in financial outlay; Japan, South Korea and Sweden have all made significant investment in fibre optic networks.

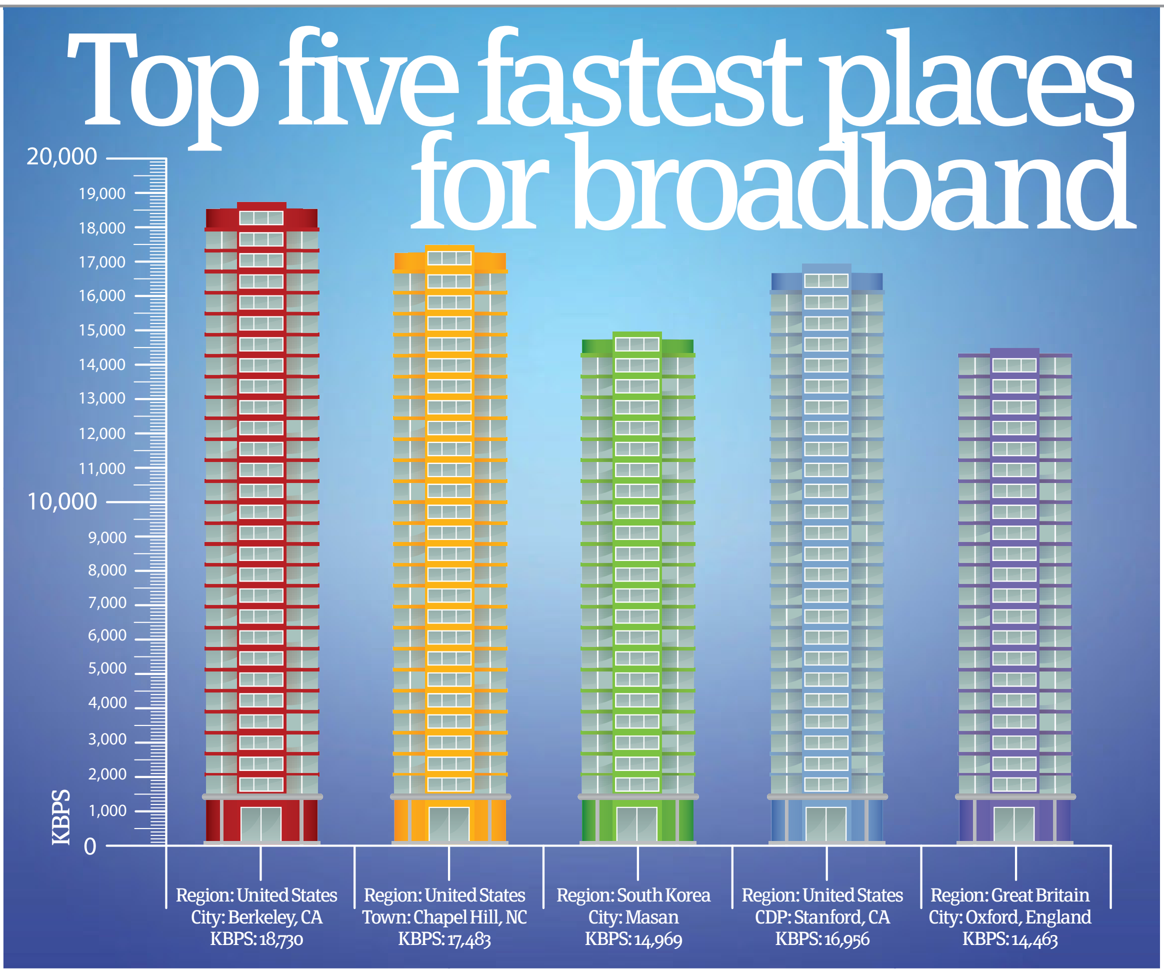
Urban density plays its part in the disparity too. Much of the population in South Korea live in very dense apartment complexes. Most of the superfast broadband service has been delivered by fibre optic connections into the basements of buildings like these, then to the individual apartments by fast DSL. So while the fastest broadband connection in the world currently resides in the UK (see below) this is unlikely to see domestic role-out soon due to the prohibitive nature of upgrading the existing network.



The fastest broadband in the world

From the 20 March 2010, the title of world's fastest broadband supplier was awarded to Virgin Media after it demonstrated its 200Mbps service trials at Earls Court, London. That speed is four times faster than its current top-end 50Mbps connection and twice that of the already reported 100Mbps connection due at the end of 2010. Virgin achieved this record speed by using the DOCSIS 3 (Data Over Cable Service Interface Specification) international telecommunications standard that allows for high-speed data transfer over an existing hybrid fibre coaxial infrastructure. Despite the epic speed, the service is not currently commercially available, however, and an early estimate has put it being introduced, depending on demand, in mid 2012.

Top five fastest places for broadband

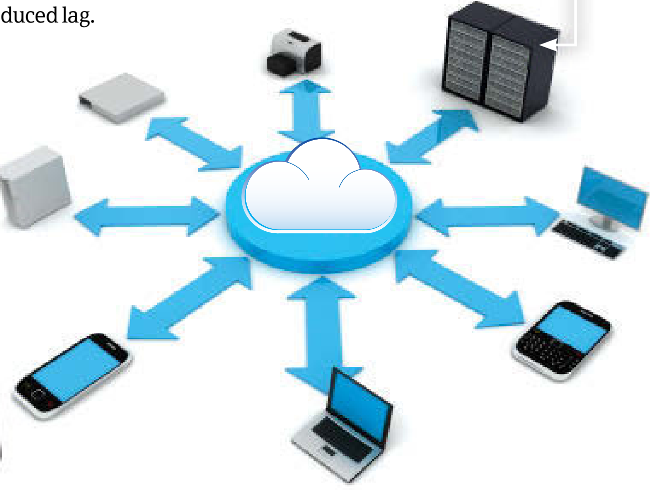


What can superfast broadband be used for?

New devices are making the most of increased bandwidth

Cloud computing, online gaming, digital downloads and live streaming of television and films are but a selection of the possible services fibre optic broadband can be utilised for. Indeed, already a host of applications and services are being set up to exploit the benefits fibre optic broadband brings. NetFlix, for example, allows for an unprecedented selection of titles – both from the current season of television, classical film archives and new Hollywood releases – to be instantly streamed live over the internet with no waiting or downloading. Gaming services like Steam allow for titles to be bought online, then downloaded and played instantly without the buyer ever needing to leave the house. Online gaming is also quicker and users experience lower ping rates and reduced lag.

Cloud computing
Content is stored online and accessed remotely from hardware devices. CLoud computing will be advanced with widespread superfast broadband.



How do QR codes work?

QR codes allow symbols, phrases and URLs to be hidden from sight. But how do they work?

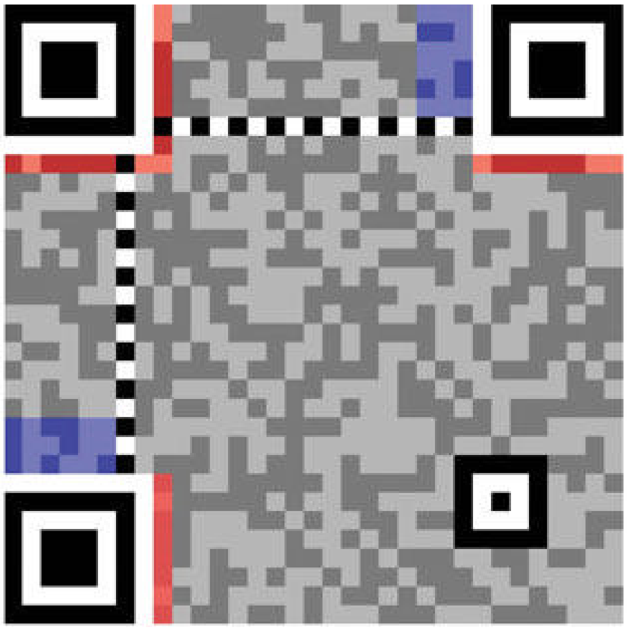
Why not download an app and reveal the QR code above.

By holding a smartphone's camera up to the sign, the user's browser sends them to a company's website

© Nicolas1981

A QR Code (QR stands for `quick response') is a two-dimensional matrix barcode that consists of a series of black modules arranged in a square pattern on a white background. They work by embedding a series of information within pre-set boundaries, the data being located and identified by a series of alignment, timing and positional patterns within the code.

The codes are read by scanners and smartphone cameras installed with a QR-deciphering software (these tend to be freely available as apps, or in some cases, are natively installed in the phone's firmware). In practice, this allows any smartphone user to hold their device up to a QR code and decipher its encrypted data, receiving a message, image or URL link.



🟦 **Version**
There are multiple iterations of QR, with its version denoted here.

🟥 **Format**
As with the QR version, there are multiple formats such as QR code, Micro QR code and Standard QR code. Its format is denoted here.

▨ **Correction keys**
Data and error correction code words maintain accuracy of translation.

▦ **Data**
The required pattern to generate the code. This varies depending on length and complexity.

▣ **Position**
This part of the QR code acts as guide markers for the video-capture interface, letting it know where the central data is.

▣ **Alignment**
Another guidance marker, which is designed to aid scanning alignment.

⋮ **Timing**
Timing strips help the decoder application determine the data's co-ordinates.

Due to the addition of colour the QR code to the left will not work. However, why not try to read the one above.

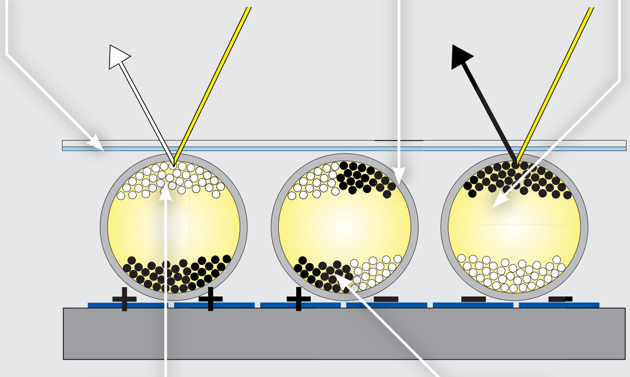
Electronic ink explained

Used increasingly in digital products, how does this technology work?

Electronic ink (or electrophoretic ink) consists of millions of microcapsules. Each one contains positively charged white particles and negatively charged black particles, all suspended within a clear fluid. When these microcapsules are subjected to a positive or negative electric field, the corresponding particles rise to the top, becoming visible to the eye and colouring that microcapsule.

eBook reader displays coat electronic ink onto a sheet of plastic film, which in turn is laminated to a layer of circuitry. This circuitry forms a pattern of pixels that can be controlled by the display's software driver, allowing images and text to be displayed in the form of a traditional page of physical paper.

Electronic ink displays differ from LCDs by utilising ambient light to illuminate pixels, with the rays merely reflecting off their surface. This means they have very low power demand, as the only energy needed is that necessary to refresh the pixel pattern each time the display changes. Also, glare from natural light enhances the display's vividness.



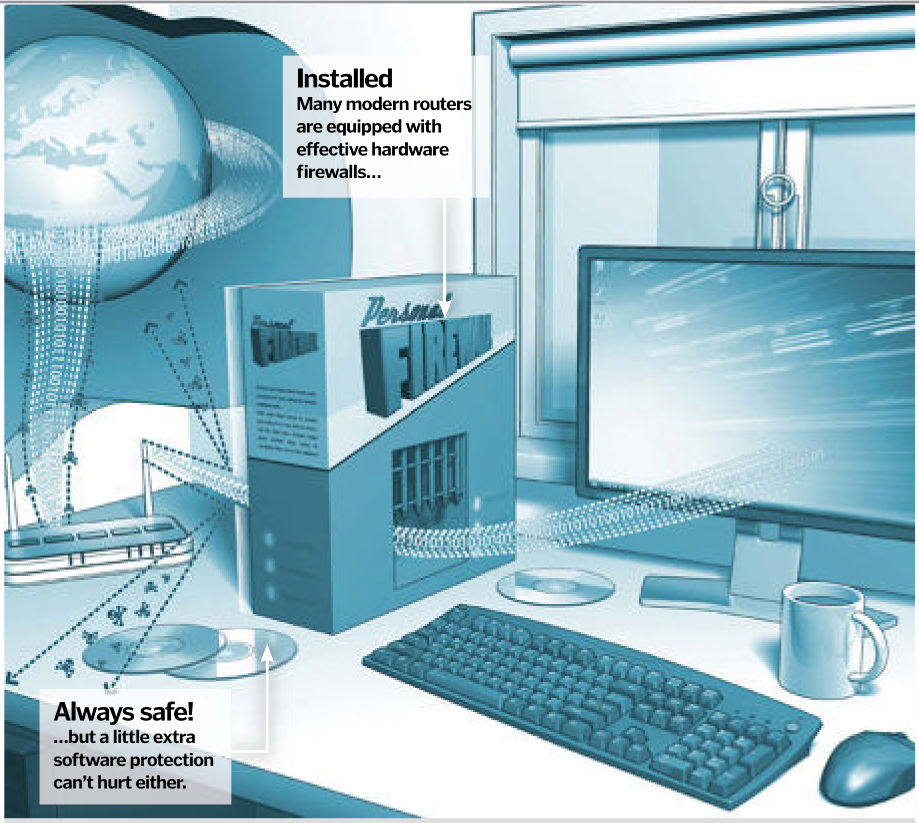
Electrodes
Forming the top and bottom boundary layers of the display screen, the electrodes house the E Ink's subcapsules.

Subcapsules
Micro containers the width of a human hair, the subcapsules contain the E Ink's pigment chips.

Clear fluid
A viscous, clear fluid that maintains subcapsule shape and suspends the E Ink's pigment chips.

White pigment chips
When the subcapsules are positively charged the contained white pigment chips rise to the top, presenting white to the viewer.

Black pigment chips
Equally, when the subcapsules are negatively charged the black pigment chips rise to the top, presenting black to the viewer.

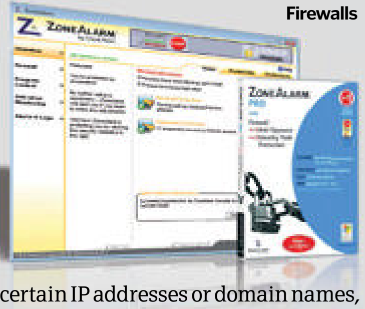


Installed
Many modern routers are equipped with effective hardware firewalls...

Always safe!
...but a little extra software protection can't hurt either.

Protect your PC with firewalls

Your PC is under attack – defend it!



ZoneAlarm is one of the most popular free Firewalls

Hackers, viruses, spyware and trojans are ganging up on us, threatening the safety of our computers and, heaven forbid, our privacy. Attacks come from people using the internet. They send rogue data to your PC via the phone lines or enable spyware to send private details out. Without a firewall, you leave your computer open to attack but put one in place and your PC becomes much more secure, giving you peace of mind. It is important to fight back and that is where a firewall is essential.

In simple terms, a firewall monitors and filters the information that travels through your internet connection into your PC. Think of a firewall as a physical brick construction in a building that prevents fire spreading from one area to another. Firewalls have filters that allow certain data to pass and others to be halted at the gate. The filters can block certain IP addresses or domain names, control particular protocols, give access to certain ports and bar others, or discard any information with undesirable words and phrases. Firewalls can be set up in one of two ways – they can allow all traffic to flow until certain criteria is met or they can prevent all traffic until certain criteria is met. Either way, a good firewall analyses and checks both inbound and outbound traffic against the filter's set of rules, discarding any rogue data. This not only prevents damage to your PC but also helps to stop spyware sending out any data you wish to keep private.

It is possible to buy a hardware firewall too. It operates as a standalone device, such as a router, that is configured via a web-based interface. Hardware firewalls tend to be used to protect networks of computers and are not essential for home computing.

IBM's Roadrunner

How many processors does it require to compute at the speed of 10,000 PCs?

IBM's Roadrunner supercomputer was once the fastest on the planet. It's designed to run at 1.7 petaflops although the maximum it has achieved is 1.4. But don't think that's below standard – take a look at how its speed is measured.

FLOPS, which stands for FLoating-point Operations Per Second, is the unit of measurement that governs how much data a computer can crunch. It's measured by the quantity of a particular kind of sum it can do (a floating-point operation) every second. Your average desktop Mac or PC can do a gigaflop or so – that's about a billion floating point operations a second. To understand the power of the Roadrunner, you need to multiply that by roughly a thousand, and a thousand again – a teraflop is equal to 1,024 gigaflops, and a petaflop is equal to 1,024 teraflops.

The Roadrunner can get nearly 445 megaflops for every watt of power it uses, making it the fourth most energy-efficient computer in the world. This may be thanks to its design: Roadrunner is made out of lots of other computers that have been stripped down to remove non-essentials. Powered by nearly 18,000 processors, Roadrunner is a mixture of IBM's own brand and AMD's dual-core Opteron chips. Despite its sci-fi looks and super speed, much of it is made from off-the-shelf parts. It is called a cluster computer – a supercomputer made of other computers – and it's configured in a way known as Triblade, made up of sections comprising two AMD chips and eight IBM ones with 16GB of RAM apiece. Roadrunner has a total of 3,240 clusters working concurrently, which powers its awesome number-crunching speed.

Inside the MacBook Pro

Beyond its sleek and slimline design, what exactly goes on inside Apple's premium portable computer?

Apple is a company that prides itself on staying ahead of the game, and the MacBook Pro is the current flagship in its portable computer line-up. A number of revolutionary features make the MacBook Pro the envy of the computing world, from its popular unibody enclosure to its groundbreaking Thunderbolt connection port. Not surprisingly such innovative technology also comes at a premium cost, with the MacBook Pro starting at a pretty tasty £999 ($1,199).

Apple started building the Pro model in 2008 using a revolutionary unibody enclosure, moulding a single piece of aluminium to create the entire chassis of the computer. All of the parts then slot into the ridges and folds within the chassis, eliminating the need for clips, levers and other internal parts. As well as efficient design, features such as the MacBook's highly recyclable aluminium material have enabled Apple to create one of the most environmentally friendly laptops available.

Another standout technology employed in the MacBook Pro is the Thunderbolt connection, which it houses on the side of the device next to the standard USB, FireWire, Ethernet and power ports. This was developed in tandem with computer processor manufacturer Intel to provide a connection that could support 10Gbits per second – 22 times faster than USB 2.0. Based on well-known PCI technology, Thunderbolt works by splitting the signal up and then reforming the pieces as part of the process.

The same touch technology that Apple incorporates into its now-ubiquitous iPhone is packed into every new MacBook. The 'Multi-Touch' trackpad allows for simultaneous touch recognition, which in turn can interpret gestures. That means users can use the same swipes and pinches they use on the iPhone to control and easily interact with their computer.

An innovative graphics setup also features, of which some graphics are dealt with on the main computing processor while others are offloaded to a separate chip. This allows the computer to run for longer periods when not using graphics-hungry apps, and more efficiently when it does. The combination also results in significantly better battery performance than similar products currently available on the market.

Here we reveal what goes on in the MacBook, and how this technological beast works. To save damage to your beautiful piece of kit, we've even taken one apart to show you exactly what's inside…

The statistics…

MacBook Pro 15"

Dimensions: 2.41 x 36.4 24.9cm (0.95 x 14.35 x 9.82 in)

Ports: MagSafe power, Gigabit Ethernet, FireWire 800, 2 x USB 2.0, Thunderbolt, audio line in/out, SDXC card, Kensington lock

Networking: Wi-Fi wireless networking2 (based on IEEE 802.11n spec), IEEE 802.11a/b/g compatible, Bluetooth 2.1 + EDR wireless technology, 10/100/1000BASE-T Gigabit Ethernet (RJ-45 connector)

Processor: 2.0GHz/2.2GHz quad-core Intel Core i7 processor with 6MB shared L3 cache, or optional 2.3GHz quad-core Intel Core i7 processor with 8MB shared L3 cache

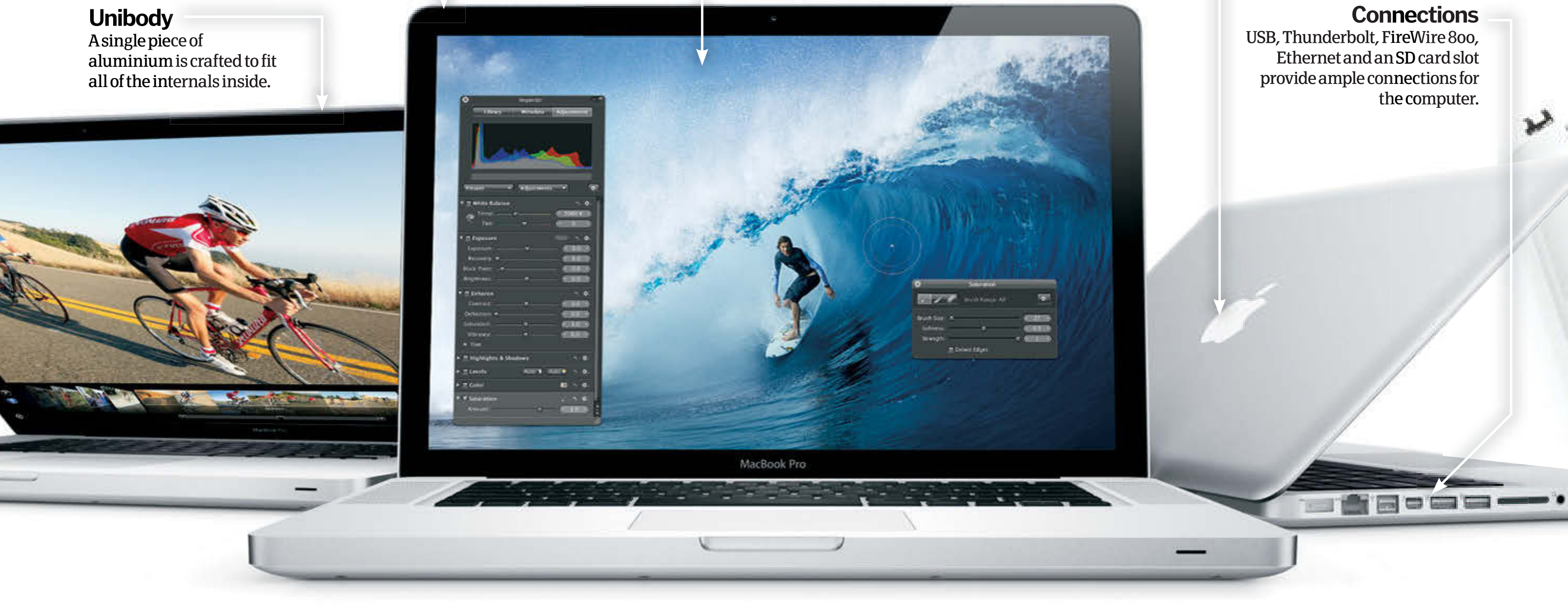
RAM: 4GB of 1333MHz DDR3 memory, two SO-DIMM slots support up to 8GB

Graphics card: AMD Radeon HD 6490M graphics processor with 256MB of GDDR5 memory on 2.0GHz configuration, or AMD Radeon HD 6750M graphics processor with 1GB of GDDR5 memory on 2.2GHz configuration, Intel HD Graphics 3000 with 384MB of DDR3 SDRAM with main memory

Camera: FaceTime HD camera

Display: Dual display and video mirroring

The Pro's main features



World-class design
Hundreds of hours are put into every aspect of the design, including the magnets that put the computer to sleep when you close the lid.

Unibody
A single piece of aluminium is crafted to fit all of the internals inside.

Screen
No expense is spared, and each screen is an HD panel with stunning resolution.

Branding
As with all its computers, Apple branding is incorporated seamlessly into the design.

Connections
USB, Thunderbolt, FireWire 800, Ethernet and an SD card slot provide ample connections for the computer.

5 TOP FACTS
MACBOOK PRO FEATURES

Fast processor
1 The MacBook Pro uses Intel quad core i7 processors, which means it demonstrates an impressive four times the processing capability of a regular microchip.

Build your own
2 When you buy a MacBook you can customise it to suit. You can configure such options as the type of drive, amount of RAM and kind of display you would like.

HD
3 It's not just a computer – each MacBook Pro also comes with a high-definition display that you can use to watch HD movies and TV shows. Great for when you're on the move.

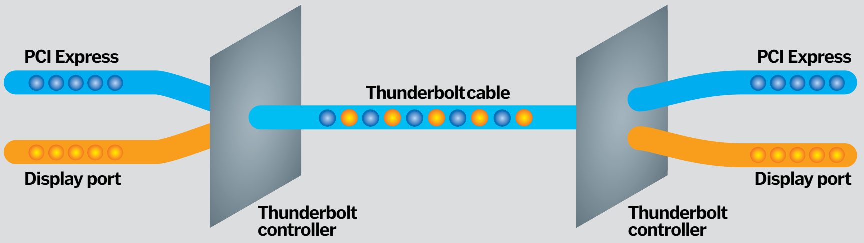
Solid state
4 It is possible to configure your MacBook Pro with a solid-state drive rather than the traditional platter drive. Solid-state drives are much quicker as they have no moving parts.

Wireless
5 Apple uses wireless 802.11n wireless capability. This is incredibly fast and allows you to connect to the web without wires and without losing much connection speed.

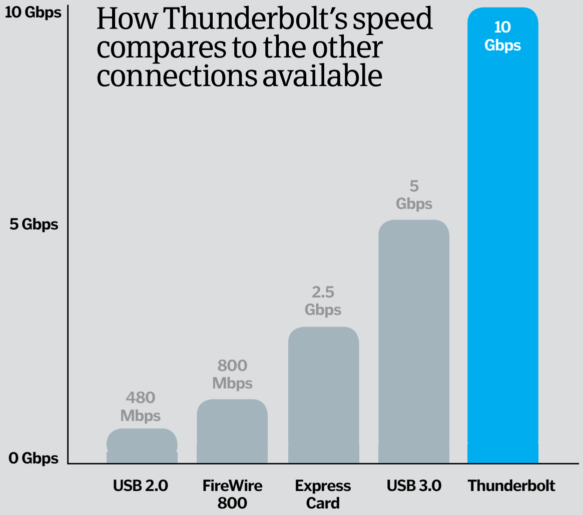
DID YOU KNOW? *The 'green' MacBook Pro is lead-free, BFR-free, PVC-free, mercury-free and uses arsenic-free glass*

Thunderbolt

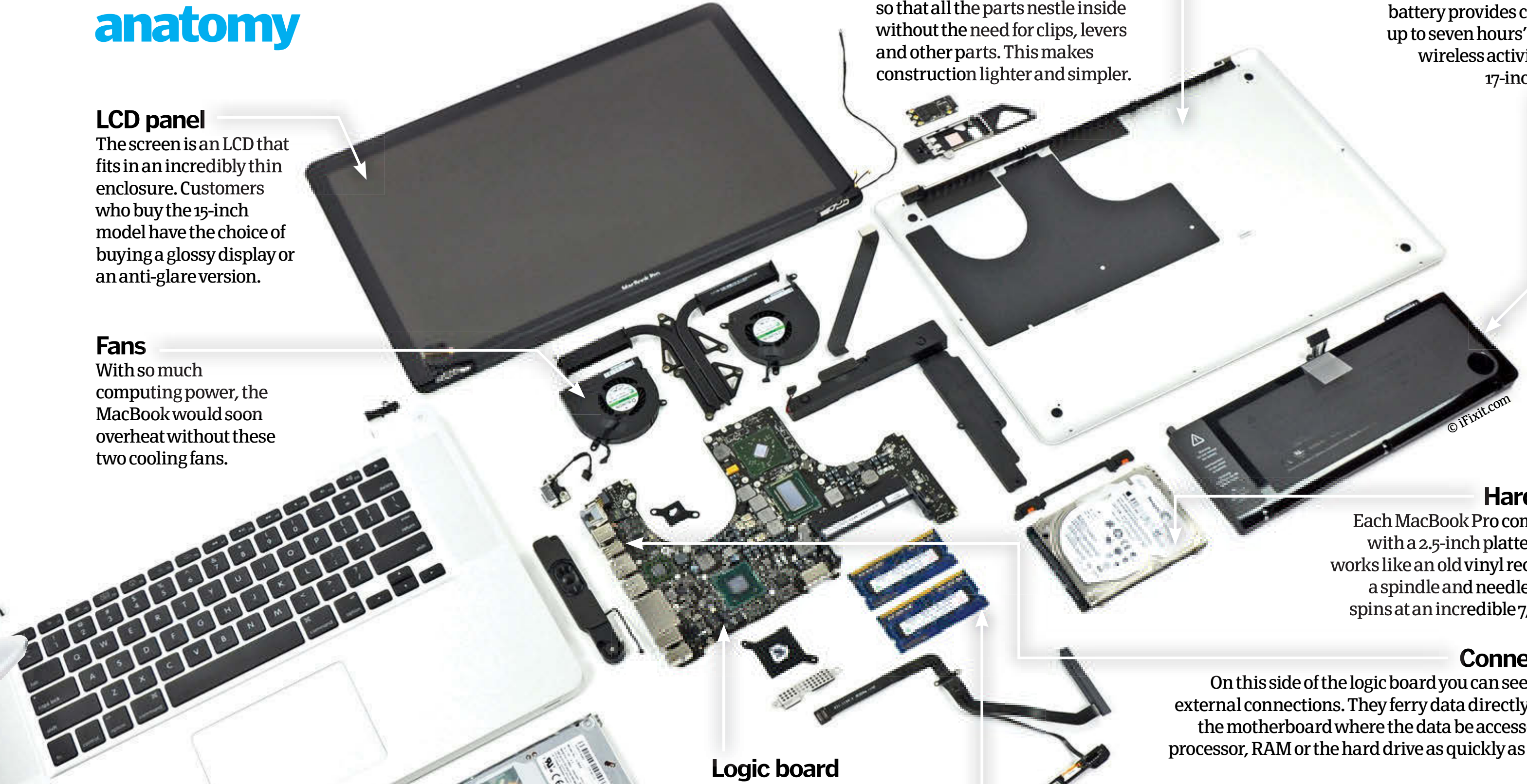
Thunderbolt uses layers, or strands, of connecting wires. At present the technology is based on the same copper wires that run your phone line, but they are still capable of reaching the incredible speed of 10Gbits per second. Eventually, Thunderbolt will be constructed using fibre optics, increasing the amount of data that can be transported and the distance over which the data can be sent. The copper wire version is limited to three metres and 'daisy-chaining' seven devices. The reason Thunderbolt is such an exciting new technology is that it will soon combine all of the existing connections you have – USB, FireWire and Ethernet – and run them from a hub through a single wire into a single connector. This paves the way for a laptop with just one port on its side.



Thunderbolt speed graph



MacBook Pro anatomy



LCD panel
The screen is an LCD that fits in an incredibly thin enclosure. Customers who buy the 15-inch model have the choice of buying a glossy display or an anti-glare version.

Fans
With so much computing power, the MacBook would soon overheat without these two cooling fans.

Unibody
The unibody enclosure is designed so that all the parts nestle inside without the need for clips, levers and other parts. This makes construction lighter and simpler.

Battery
The biggest element, the battery provides charge for up to seven hours' web and wireless activity on the 17-inch model.

Hard drive
Each MacBook Pro comes fitted with a 2.5-inch platter drive. It works like an old vinyl record with a spindle and needle, but this spins at an incredible 7,200rpm.

Connections
On this side of the logic board you can see all of the external connections. They ferry data directly through the motherboard where the data be accessed by the processor, RAM or the hard drive as quickly as possible.

Logic board
Miniaturisation means all the computing you need is crammed into this tiny logic board. Every electrical operation is carried out here.

RAM
These two tiny chips can provide up to 8GB of RAM. They provide the computer with all the data it needs to run your applications.

Optical drive
MacBook Pros come with an optical DVD drive. Its slot-loading and manages to fit inside the sleek unibody enclosure. Apple has yet to adopt any HD Blu-ray drives.

A lot of ports for such a slimline machine…

© iFixit.com

Learn more

For more information and images of the exposed MacBook Pro, visit the gadget surgeons at **ifixit.com** who kindly contributed photos and findings for this article.

The iPad is dependant on Wi-Fi connectivity

Antenna
Wireless signals can be transmitted to many devices

Wi-Fi explained

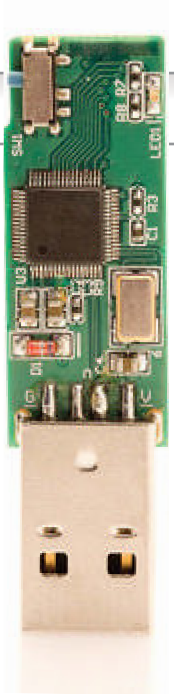
How can data be transferred wirelessly to your laptop?

Many electronic devices such as laptops, games consoles and mobile phones can be connected to the internet – or to each other – securely, quickly and wirelessly, using radio frequencies instead of cables to transmit data.

A wireless network comprises a source computer connected to the internet using an Ethernet cable, a router to translate data (1s and 0s) into a radio signal and an antenna inside the wireless device to pick up the signal. Like using a walkie talkie, sending information via radio waves requires the frequency bands to be broken down into channels to avoid outside interference.

To enable, say, a laptop to connect to a wireless network, the laptop requires a wireless adapter, which can both send and receive data to and from the network router, which can also send and receive data. Both devices are fitted with decoders, which convert radio signals into digital form. When you want to connect your laptop to the internet, the adapter communicates with the router via radio signals. The router decodes the signals and – via the Ethernet connection – fetches the relevant data from the internet. This info is converted into radio signals and sent to the laptop's wireless adapter where it is decoded, giving you the internet page you requested.

Impressive technology that we take for granted



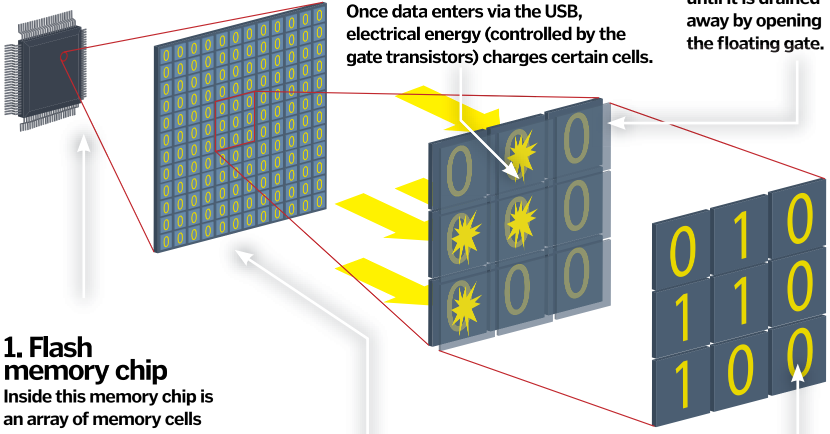
How do flash drives work?

Find out how these versatile plug-and-play devices can store data

Similar in nature to a conventional hard drive, a flash drive is a very convenient device capable of not only storing data, but also transferring it quickly between computers and digital devices. A form of solid-state storage (electronic, with no moving parts), flash drives are both robust and small enough to fit in your pocket and yet can hold vast quantities of data depending on how great their storage capacity. Flash memory is a type of EEPROM (Electrically Erasable Programmable Read-Only Memory) stored as small blocks. The chunks of data stored using flash memory can be erased and re-programmed electronically, making it a quick, effective way of transferring files.

When you insert the flash drive into the computer's USB port, the computer automatically detects the device. It then acts like an external hard drive, allowing you to immediately begin storing and retrieving data. The internal workings of a flash drive consist of a small printed circuit board (PCB) that features some power circuitry and a few mini integrated circuits: one of these circuits provides an interface to the USB port, one drives the memory, and another – perhaps the most important – is the flash memory as you can see from our annotation.

The flash memory chip inside your storage device



1. Flash memory chip
Inside this memory chip is an array of memory cells and two gates – a floating gate (electrically separate from the rest of the device and surrounded by a thin oxide layer) and a control gate transistor that affects the flow of electricity.

2. Enlarged memory cell
Each memory cell contains binary code in the form of 0s and 1s. When no data is stored, the cells are all set to 0 because the voltage on the gate is blocked.

3. Electrical charge
Once data enters via the USB, electrical energy (controlled by the gate transistors) charges certain cells.

4. Thin oxide layer
The electrical charge pierces the oxide layer until it is drained away by opening the floating gate.

5. Stored data
The charge becomes trapped on the oxide and the cells become 1s. This pattern of 0s and 1s is stored as data in the memory.

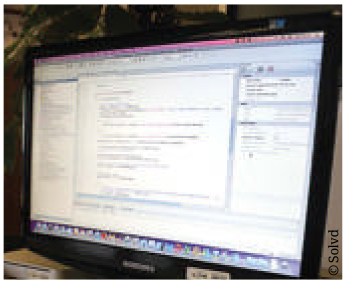
App development in five steps

Creating your own app is more straightforward than you think…

© Solvd

1. Design
First you'll need to sketch out how you want your app to look, and then use a stencil tool such as UI Stencils to translate this to an iOS or Android building tool.

2. Build
Buttons and user interface elements are laid out in an Interface Builder, using programs such as Xcode and MonoTouch to define where and how things are placed.


© Solvd

3. Code
Development applications such as MonoTouch, MonoDroid and Xcode are used in tandem with the Apple and Android development kits to develop the app into a working program.

© Solvd

4. Refine
Once you have a good, solid system working in the iOS or Android developer kit simulator, the app can be loaded onto an iPhone or Android device for testing.

Available on the App Store
© Apple Inc

5. Submit
An application submission pack can now be created with the digitally signed app, and, if approved, the app can be uploaded to the App Store or Android Market for others to download.

How to make an app

From design to submission, how do you make the perfect app?

App development relies on the Apple and Android developer kits and a variety of third-party software to turn your idea into reality. The official developer kits come with most of the software you'll need to make your app, including coding and simulation programs.

The first part of app development is designing how your app will look. For this you'll need stencil equipment, supplied from companies like UI Stencils, to sketch out your app design. These physical templates allow you to sketch the layout of each page to determine button layout, image locations and other information.

Once happy with your design, you'll need to build the app in an Apple or Android environment. This can be done on programs such as Xcode and MonoDroid, which let you code in C – a computer programming language that creates lists of instructions for a program to follow – so you can visibly see the results of your actions. This allows you to build links between pages on your app and assign functions to buttons.

Once you have finished building your app, it must be loaded into a simulator supplied with the developer kit for testing. You can then load it onto your iPhone, iPad or Android device for further debugging, until it's ready to be uploaded onto the App Store or Android Market, following a brief submission process. ✿

Learn more

If you aren't ready to build an app yourself, Solvd Limited provides all the services you'll need to make an app for Android, Windows 7 and Apple devices, in addition to web design and systems consultancy. Find out more at **www.solvd.co.uk**.

4G mobile INTERNET

The next generation of mobile networks is now upon us – 4G is bringing speeds so fast, our phones will soon be downloading movies in seconds

5 TOP FACTS MOBILE PHONE HISTORY

1835

1 Samuel Morse made the first working electric telegraph to send and receive complex messages, and in 1844 he sent the first message: "What hath God wrought?"

1973

2 Motorola engineer Dr Martin Cooper made the first handheld mobile phone call to his invention rival Joel Engel at AT&T in 1973.

1985

3 First-generation (1G) mobile phones entered the market in the Eighties. They were large and heavy devices with limited battery lives that could only make voice calls.

1992

4 The introduction of the 2G network allowed for text messaging and basic internet access, and by 1999 76% of the UK owned a mobile phone.

2001

5 Japan launched the first 3G network, bringing with it faster mobile internet, and by 2007 there were a total of 200 million 3G users worldwide.

DID YOU KNOW? South Korea claims to have the fastest 4G network in the world, 40 times faster than 3G

4G war in the US

All four major mobile operators in the US are running or rolling out a 4G network, promising much higher speeds than existing 3G networks. At the moment the speed of 4G in the US more closely resembles a faster 3G service – dubbed '3.5G' – because true 4G is defined as a speed of 100MB to 1GB per second. However, the International Telecommunication Union (ITU) has sanctioned the use of 4G on current technology. Here's how the competitors match up…

T-Mobile

Operational in 100 urban centres in the US, T-Mobile is currently using the HSPA+ technology. This doesn't have the capacity to reach true 4G speeds of 1GB/s but, under current ITU guidelines, it's referred to as a 4G service rather than 3.5G.

Verizon

Verizon's 4G LTE service is already up and running in 38 US markets and is currently the most widely available 4G service. Upcoming phones such as the HTC ThunderBolt will be ready to make use of the service, promising download speeds of up to 12Mbps and coverage for two thirds of the US population by 2012.

AT&T

AT&T has chosen to run its 4G service using High Speed Packet Access + (HSPA+). Although this is currently quite fast it doesn't compare to WiMax and LTE, so AT&T will switch to the latter this year and add to its existing HSPA+ service.

Sprint

Sprint has aggressively backed WiMax in the 4G war, unlike its competitors who have largely thrown their weight behind LTE. Sprint is rolling out its 4G service throughout 2010, but it's comparatively slower than its competitors.

SAMSUNG
verizon
THUNDER BOLT
10 08
10 54

Stats – 1st
Technology: Long Term Evolution (LTE)
Available: Now
Smartphone: HTC ThunderBolt
Download speed: 5-12Mbps

Stats – 2nd
Technology: High Speed Packet Access + (HSPA+)
Available: Now
Smartphone: Samsung Galaxy S
Download speed: 5-10Mbps

Stats – 3rd
Technology: HSPA+/LTE
Available: Now/Q3 2011
Smartphone: HTC Inspire
Download speed: 6Mbps

Stats – 4th
Technology: WiMax
Available: Q3 2011
Smartphone: HTC Evo
Download speed: 3-6Mbps

Internet on the go has never been so easy

The advancement of mobile phone technology has been stupendous, progressing from bulky and heavy machines to sleek and stylish smartphones in just two decades. With this upgrade in hardware has come a significant leap in software, and today's phones are now able to do almost everything we'd expect to do on a home computer. The introduction of 3G was pivotal for mobile technology, allowing internet on the go whenever you wanted it. Now as 4G is introduced, we'll begin to see lightning-fast download speeds on our mobile devices.

4G aims to improve upon the already existing 3G service and provide speeds that will rival and even surpass those of our home networks. The official definition of 4G, according to the International Telecommunication Union (ITU), is a service that can provide speeds of 1 gigabit per second when stationary and 100 megabits per second when moving, as movement makes data transfers harder. However, many companies – particularly in the US – are already beginning to roll out what they claim to be 4G networks.

In reality, these are more clearly defined as 3.5G, but the ITU has allowed the term 4G to be used despite network speeds still being some way off. However, true 4G will not be achieved until download speeds of 1GB per second are possible.

Mobile Internet began with the Wireless Application Protocol (WAP), used on early mobile phones to provide a basic and stripped-down version of full HTML internet. However, modern smartphones are more than capable of dealing with the complexity of running HTML internet, and as such they no longer need to rely on WAP to provide users with a diminished web experience. We can access full webpages on our phones whenever we need them – and at speeds similar to those we experience in the comfort of our own homes – but 4G makes things much faster.

Smartphones send and receive data (such as webpages or phone calls) across regular mobile network technology, using computational protocols to complete an allocated task. Data is transmitted as packets of digital information in radio waves on specific frequencies to and from your phone. The reason 4G will be able to achieve high speeds of 1GB per second is that all of its data will be transmitted in these packets, whereas in the past these digital packets only controlled part of the flow of information.

Going as far back as 1G, both voice and data were handled by circuit switching. This meant transmissions were in ordered time slots, a slow and restricted service that limited phones to voice calling only. 2G phones, while digital, also still relied on circuit switching for voice calls and data transfers, but allowed new features such as text messaging to be possible with faster transfer speeds. 3G phones ushered in packet-switching, which meant ▶

▶ that data could be sent out and received by a mobile network tower as required with no ordered time slots. This allowed for the constant and simultaneous transmission of information, so you could use the internet while making a voice call for the first time. However, voice was still handled by circuit switching, something that 4G will advance upon when it is introduced. Everything will be packet-switched, allowing data to be constantly sent and received at all times. This means phones will perform all of their communications functions over the internet, known as an 'all-IP network'. For the first time ever this will include voice-calling services, which will be transmitted over the internet, rather than through a network. And with more simultaneous tasks, the high speeds of 1GB per second can be achieved.

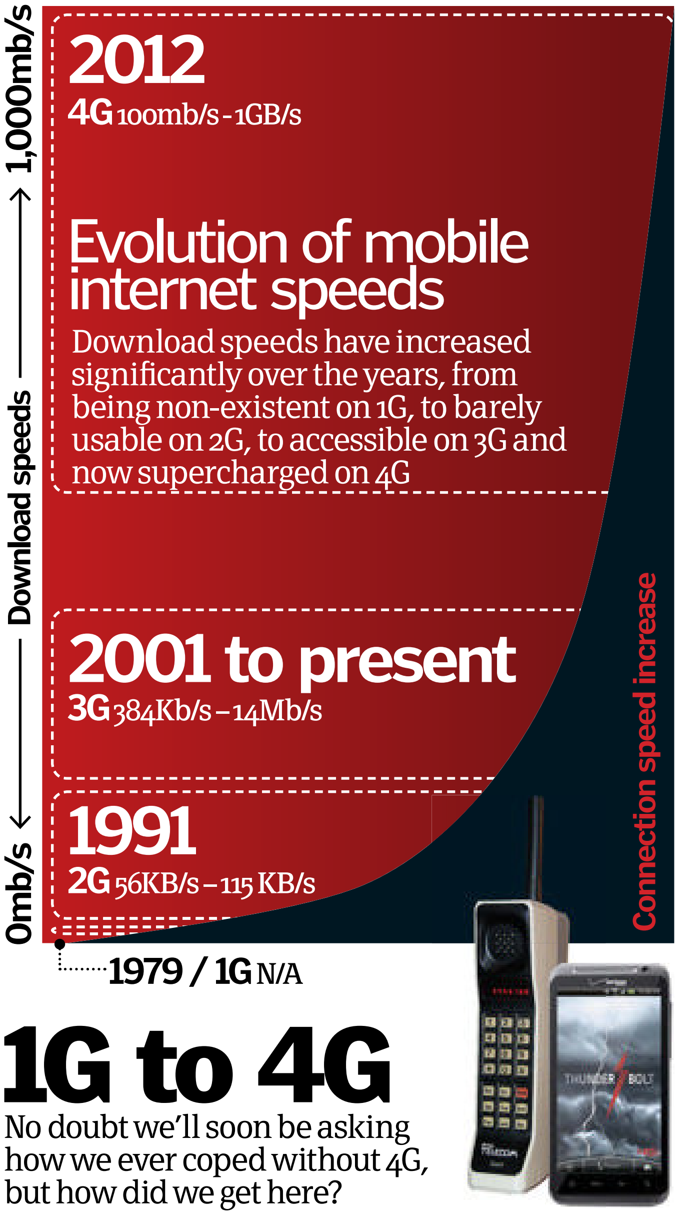
On our phones most of us have three or four ways to receive information. The first is the signal bars, which visualise the amount of signal our phones are receiving on one of two competing services, either Global System for Mobile Communications (GSM) in the UK or Code Division Multiple Access (CDMA) in the US. These technologies are generally referred to as second generation (or 2G) and are the ones responsible for connecting our calls and SMS, but they don't provide the internet service for our phones. This comes in the form of 3G or EDGE, the latter denoted by an 'E' on your phone. In some countries, like Japan, there is limited or no 2G network available and all phones connect via 3G. With the introduction of 4G, all services will be handled wirelessly across the internet.

All mobile phone services operate on a specific frequency, one that will not interfere with other forms of communication. Within this range, each mobile operator is allocated a specific frequency on which they can broadcast their service. In the UK, AM radio uses frequencies between 180kHz and 1.6MHz, while FM radio uses 88 to 108MHz. TV broadcasts within 470 and 854MHz, and mobile phones currently operate within either 872-960MHz, 1,710-1,875MHz or 1,920-2,190MHz. 4G will be allocated its own bands of frequency, upon which it will be unhindered, to provide the fastest speeds possible. In the UK, the auctioning of these frequency spectrums, around 800MHz and 2.6GHz, will take place in some time in 2012.

4G will switch to a new radio technology, either WiMax (Worldwide Interoperability for Microwave Access) or LTE (Long Term Evolution). These services operate very similarly, both replacing internet with widespread wireless internet, which will significantly increase coverage and connection speeds to mobile phones. Analysts have suggested that the battle will be akin to such previous technology rivalries as Betamax versus VHS and Blu-ray versus HD DVD. In the US, mobile operators have already begun to show where their faith lies, with Sprint backing WiMax and AT&T getting behind LTE. As we've already mentioned, however, it remains to be seen what speeds these supposed 4G networks will really achieve, and whether or not we will see true speeds of 1GB per second within the next year as these exciting services come into operation. ⚙

Today we can access mobile internet almost anywhere

WiMax transmitters can deliver 4G internet



Evolution of mobile internet speeds

Download speeds have increased significantly over the years, from being non-existent on 1G, to barely usable on 2G, to accessible on 3G and now supercharged on 4G

1G to 4G

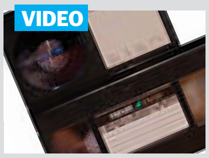
No doubt we'll soon be asking how we ever coped without 4G, but how did we get here?

Back in the Eighties, the first generation (1G) was the one that let mobile phones communicate with each another for the first time, beginning in 1979. It used an analogue cellular service known as the Analog Mobile Phone Service (AMPS) to operate, which meant data was transmitted without compression and led to the bulky 'brick' phones. Each operating on a separate radio frequency, they were the first to provide a continuous signal that allowed audio to be transmitted between devices.

The second generation (2G) of mobile phones, introduced in 1991, bears closer resemblance to what we use today. This brought with it digital cellular phones, replacing AMPS with D-AMPS (Digital-Advanced Mobile Phone Service). Rather than analogue signals, this digital service transmitted information as small electrical pulses, allowing phones to become smaller and sleeker and ushering in the age of texting. Mobile phones could now operate on the same radio frequency, allowing their use to become more widespread.

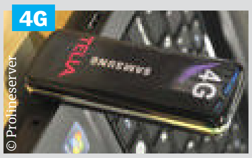
2001 saw the arrival of 3G, which significantly improved the method of data transmission over the radio spectrum and made it more efficient. In fact, the improvement was such that each phone was allocated enough bandwidth to be able to browse the internet for the first time. Today, 4G is improving upon the previous generation.

Head to Head TECH RIVALRIES



1. Betamax versus VHS
In the late-Seventies, Sony's Betamax went up against JVC's VHS videotape format, the latter emerging victorious.

2. Blu-ray versus HD DVD
Sony's Blu-ray disc format defeated Toshiba's HD DVD in 2008, to become the dominant high-definition video and audio standard.



© Prolineserver

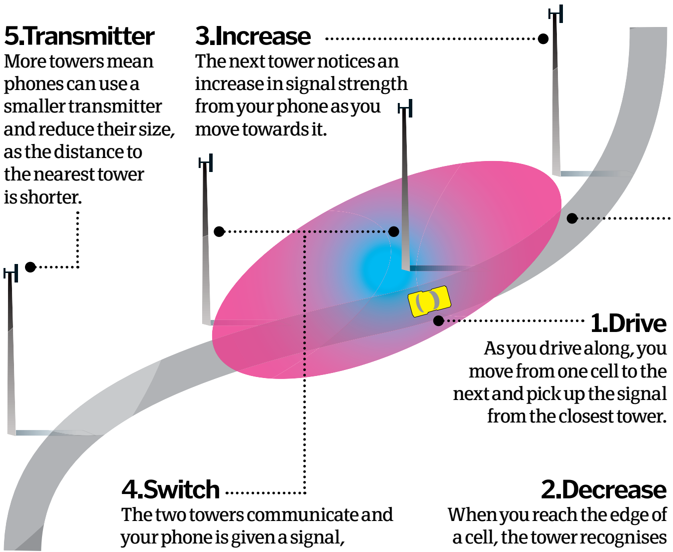
3. WiMax versus LTE
Mobile carriers are currently split over which of these 4G technologies to back, although LTE appears to be the frontrunner.

DID YOU KNOW? When the 3G spectrum was auctioned in 2000, it raised £22.5bn for the UK Treasury

Phone towers

Rising up to 100m (330ft) in the air, cell phone towers litter our landscapes. Still, they're vital for receiving a signal on our mobile phones. Many different operators will share a particular tower and emit signals at varying frequency. This will determine which type of phone can pick up the signal and which cannot, because phones are only receptive to specific types of frequency.

Your internet at home is likely broadcast around your house with a wireless router. This allows devices with a wireless signal detector to connect to the router and ultimately the internet. In essence, mobile internet works in the same way. Mobile phone towers act like giant wireless routers, emitting a signal that can be picked up by your mobile phone. Your phone will only connect when it is within a specific range of this tower, usually about 48km (30mi). Multiple towers are spread out and each emits a signal in an area known as a 'cell'. As you travel along, you move from one cell to the next and thus receive a signal from a different tower.



5.Transmitter
More towers mean phones can use a smaller transmitter and reduce their size, as the distance to the nearest tower is shorter.

3.Increase
The next tower notices an increase in signal strength from your phone as you move towards it.

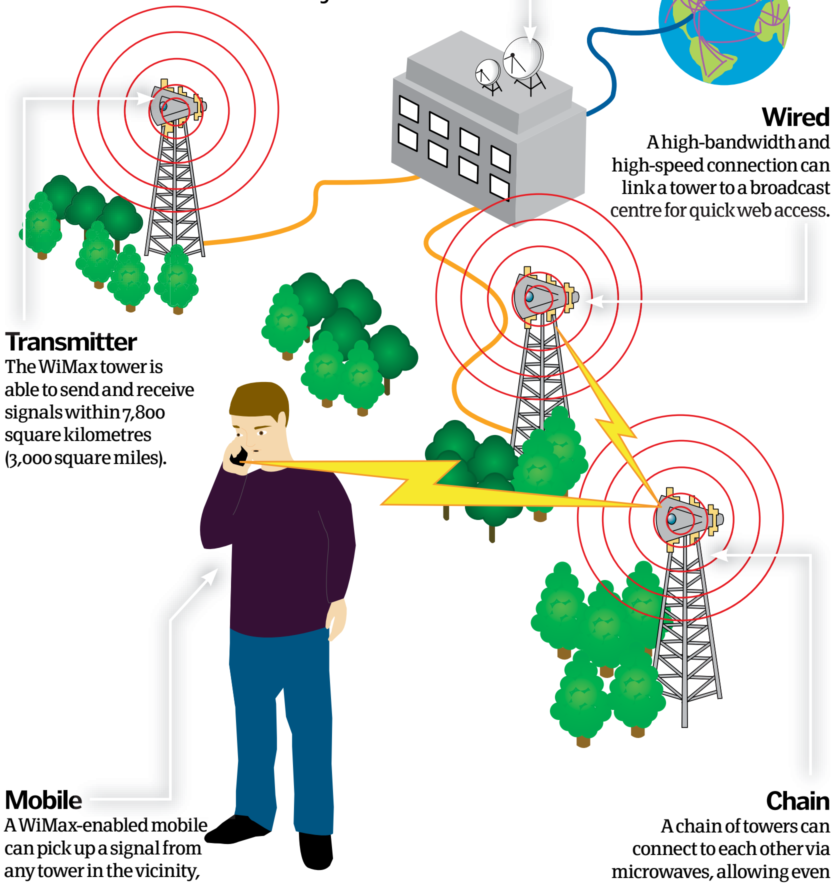
1.Drive
As you drive along, you move from one cell to the next and pick up the signal from the closest tower.

4.Switch
The two towers communicate and your phone is given a signal, informing it to switch communication from one tower to the next.

2.Decrease
When you reach the edge of a cell, the tower recognises the decrease in signal strength of your phone.

How does WiMax work?

WiMax and LTE both operate using similar technology. Here's how the internet is delivered to your mobile



Internet
A wired WiMax tower connects to the internet through regular means such as fibre-optic cables.

Wired
A high-bandwidth and high-speed connection can link a tower to a broadcast centre for quick web access.

Transmitter
The WiMax tower is able to send and receive signals within 7,800 square kilometres (3,000 square miles).

Mobile
A WiMax-enabled mobile can pick up a signal from any tower in the vicinity, for instant online access.

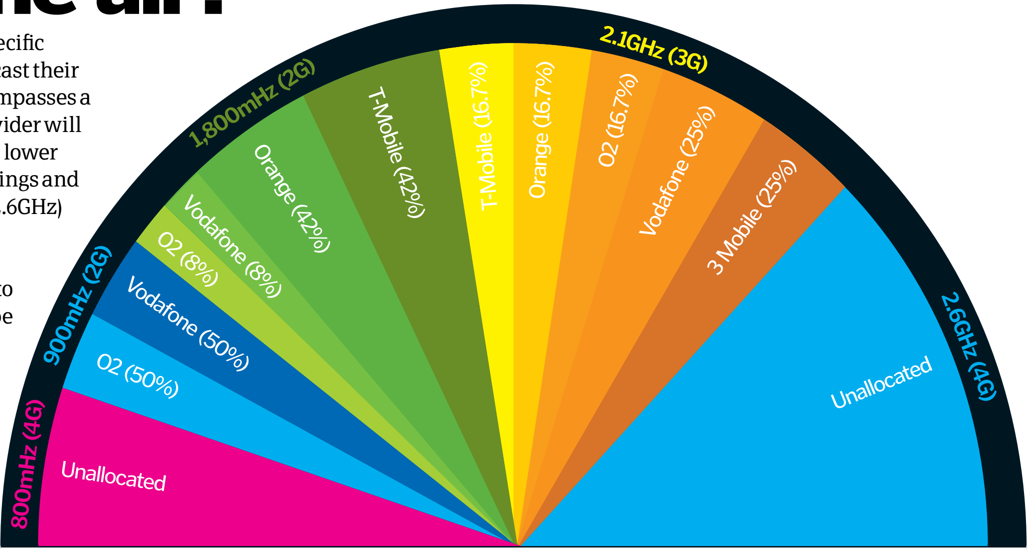
Chain
A chain of towers can connect to each other via microwaves, allowing even rural areas to receive 4G.

Who controls the air?

In every country, different mobile operators are allocated specific frequencies on the radio spectrum on which they can broadcast their mobile phone service. A band such as 900MHz actually encompasses a range of frequencies, such as 872-960MHz, and a service provider will be allocated blocks of frequency within the band. In general, lower frequencies (such as 800MHz) are better at penetrating buildings and providing signal indoors, while higher frequencies (such as 2.6GHz) are better at providing widespread coverage in a busy city.

In the UK, the 800MHz band is currently being used for analogue terrestrial television. However, with television set to switch exclusively to digital in 2012, space on this band will be freed up for 4G use. As it is a lower frequency, it is adept at penetrating buildings, whereas the higher 2.6GHz band will be more useful in urban centres for 4G.

Vodafone and O2 have been operating since the mid-Eighties, while T-Mobile and Orange appeared in the early-Nineties. This means they all acquired the early 2G allocation, while new companies such as Three operate only within a 3G frequency. The unawarded frequencies will be used for 4G and auctioned in the UK in 2012.



Note: Orange and T-Mobile merger (July 2010) under the parent company Everything Everywhere Ltd allows the sharing of signal between the two companies

The back-up diesel engines (below) are permanently pre-heated, so that in the event of a power cut they'll produce enough electricity to power all systems after just 15 seconds

All images © 1&1 Internet

Data centres

Explore 1&1's 'internet factory' to discover how these giant databanks store and protect the world wide web

When you visit a website, content is sent over the internet to your browser from a web server: a computer that stores the website data. Although any computer can act as a web server, to remain operational it must be managed under regulated conditions. This is costly, and while some of the world's major online corporations support their own server rooms, most websites and companies take advantage of the convenient web-hosting hospitality of a data centre. A business may have a dedicated server, or multiple users may share one.

These state-of-the-art facilities power tens of thousands of servers, each capable of hosting hundreds of sites. And because data centres hold sensitive information and are relied upon by businesses, they have strict security regulations and environmental controls to ensure the security of the data by staying operational 24 hours a day.

For an idea of just how much information passes through a data centre, one of the world's largest web hosting companies, 1&1, currently manages a third of all the home pages in Germany and over half the country's email inboxes. With all this sensitive data knocking about, data centres go to extreme lengths to avoid system failure. Failsafe emergency power supplies kick in so that even if the main grid suffers a power outage, service is uninterrupted.

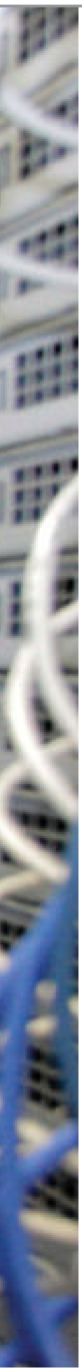
First to the rescue in the event of a power cut are four huge battery blocks. These are each capable of supporting the servers for 17 minutes, after which a fifth reserve battery block comes into action. If power still isn't returned after that time, five large 16-cylinder diesel generators on the roof of the centre kick into action and supply power to the site for as long as diesel fuel is available. During a power cut, the Karlsruhe 1&1 facility is the only light in the city.

THE STATS 1&1 INTERNET

CONNECTIVITY 210Gb MONTHLY TRAFFIC 1,000terabytes WEBSITES REGISTERED 2.7m

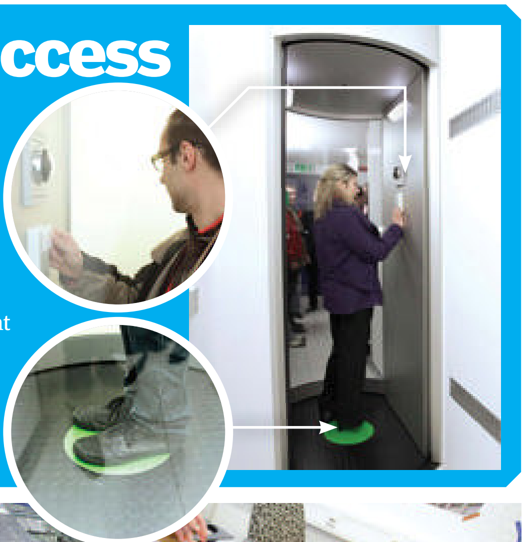
DOMAINS REGISTERED 11m UPTIME GUARANTEED 99.99% EMAILS HANDLED PER DAY 9.5m

DID YOU KNOW? 1&1's data centre in Germany manages every third webpage and over half the country's email inboxes



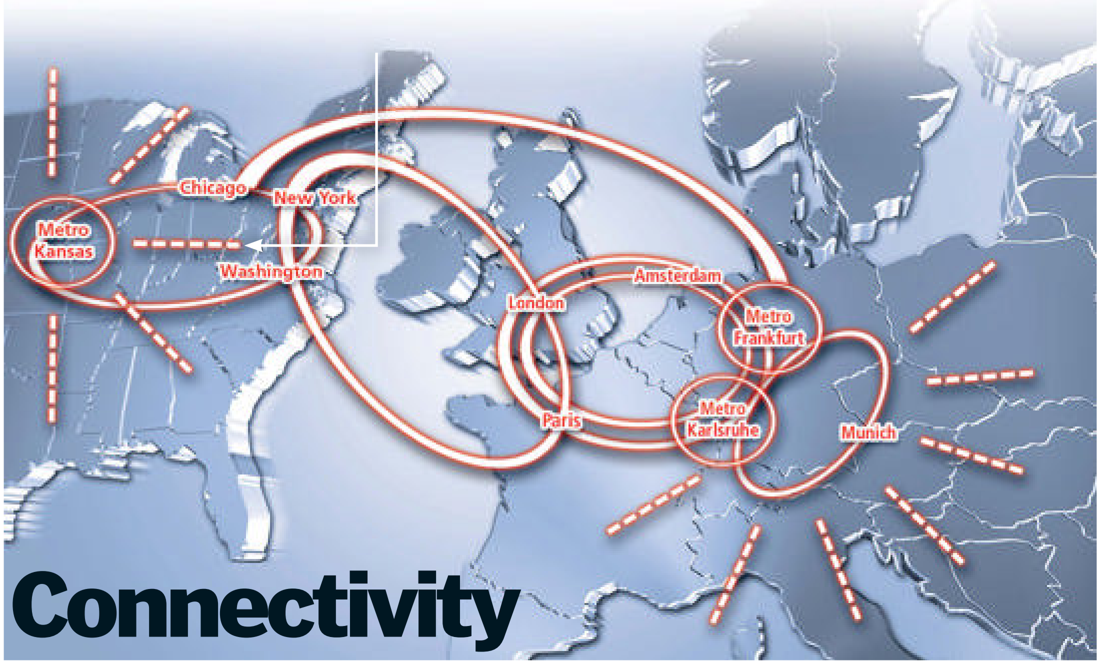
No unauthorised access

Considering the quantity of highly sensitive information within the walls of a data centre, no unauthorised access is permitted. Before an employee can even set foot into 1&1's state-of-the-art Data Centre IV in Germany, they must pass through an airlock to ensure no unauthorised entry. Any employee entering the centre must carry a valid chip card, which contains their identifying information to be confirmed by passing a series of protocols, including entering a PIN code and passing weight and biometric checks to determine the identity of the employee. Once authorised, the inner airlock door is opened and access to the facility is granted. Meanwhile, over 150 CCTV cameras watch and record the employee's every move throughout their time at the centre.



The continuous operation of all systems is a data centre's main challenge

One server rack can hold 80 servers



Connectivity

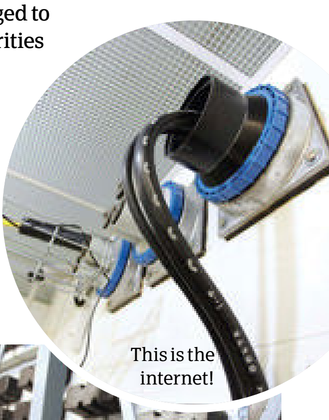
Because connection speeds are so vital – especially with the increased demands of broadband and streaming – it's essential that a web host can ensure internet users can access websites fast. 1&1, for example, has a network of data centres across the globe and 210 Gbit of external connectivity (and 1,000 terabytes of monthly traffic).

Inside the server rooms

The 11 server rooms at Data Centre IV accommodate 660 racks of servers, each capable of holding up to 80 servers all connected to the internet. The temperature in a room containing thousands of constantly running processors is therefore controlled by six air conditioners to prevent overheating.

As well as getting too hot, there are also numerous outside factors to consider when protecting these valuable servers. Every room is equipped with sensitive smoke, fire and water detectors that use laser particle detectors to check the air. In the event of a fire, the data centre is capable of dealing with the flames safely. Of course the use of water in a room full of electrics would be catastrophic; instead, 1&1 uses argon gas. Unlike carbon dioxide, which is denser than air (and sinks), or nitrogen, which is lighter than air (and rises), argon spreads out evenly across a room and chokes the fire because it is inert and doesn't react with other substances. It also leaves just enough oxygen present for people to breathe.

Meanwhile, to protect against electronic threats, 1&1 Internet has a team of 40 dedicated experts who seek out and block fraudsters, such as phishing websites attempting to obtain sensitive information from web users. Data centres are also obliged to work with the authorities and have to retain emails and data for several months, in case it's needed for criminal investigations.



This is the internet!

At full capacity, the data centre consumes 2% of Karlsruhe's total energy consumption

Who has the most servers?*

*According to the Netcraft server count report

Intel: **100,000** OVH: **80,000** SoftLayer: **76,000**

Akamai Tech: **73,000** 1&1 Internet: **70,000** Facebook: **60,000**

CREDIT - DEBIT - FINANCE
4459
VALID FROM

Phishing

The increasingly common internet crime of phishing is an act of email deception used to steal people's identities. How is it possible?

Phishing, the act of sending an email that purports to be from a reputable source in order to attain a person's financial or personal information, is an increasingly common form of identity theft. Typically, the email assumes the guise of an official correspondence from a person's bank or online retailer, asking them to update or confirm their account, often in the wake of fabricated illegal foreign use. This 'updating' is supposedly done by visiting an embedded URL link within the email, taking the victim to a faked replica website designed by the phisher to store any entered information. Information can be acquired either manually, with the victim believing they are entering it into an official system, or automatically, with automatic virus scripts activated as soon as the link is clicked.

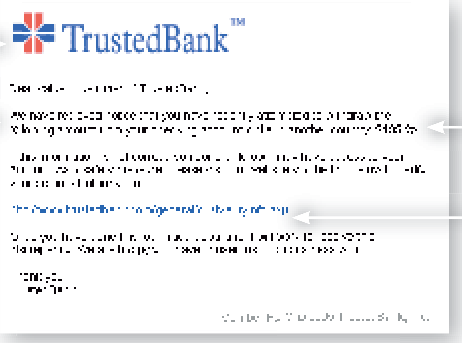
Brand

Phishing emails invent brands and companies that, while appearing realistic, are in fact fake. Logos and fictional products are used to add to the sense of authenticity. In advanced cases, phishers will replicate real-life companies such as PayPal or Amazon.

Copy

Phishing emails are often written in an authoritative manner, a style chosen to lead people into believing that they, or one of their online accounts, are under threat by alien activity. The text will usually ask them to verify that the activity is indeed false, in order for the account to be locked down.

Anatomy of a phishing email



TrustedBank™

Errors

One of the most common ways to identify a phishing attack is an uncharacteristic error in the body text or URL link. These can range from basic spelling errors – such as here, with the word received spelt 'recieved' – through to the use of subdomains like **www.google.com@member.verification.com**.

URL

Almost all phishing attacks use the fraudulent email medium to link into a purpose-built site, specifically honed to make it easy for them to collect the victim's personal information. This is either entered by the tricked victim, or done by automated software scripts (ie, viruses).

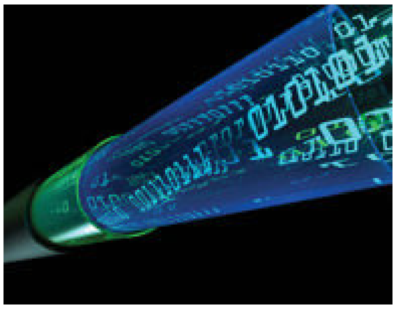
The term used to describe the reduction in intensity of the light waves is 'attenuation'

Fibre-optic internet

The next generation of communication will speed up download times using state-of-the-art fibre-optic technology

In today's culture of internet TV and streaming media there's a growing demand for extremely high transmission speeds to allow for such data-intensive services. Although traditional copper wire has served internet users well until now, it may just have run its course. A more reliable and efficient system of fibre-optic internet is now providing ultra-fast connection speeds while also solving the problem of increased internet traffic.

The main problem with copper wire is that the speed of data transmission is rapidly reduced as the length of the wire increases, meaning connection speeds can vary depending on how far away from a telephone exchange the user is located. Fibre optics, meanwhile, have no such restrictions. Optical fibre sends information through a process called total internal reflection. Each fibre is made up of a transparent inner core, along which the signals are transmitted. An outer casing lined with a reflective material then bounces the signals back into the core whenever they hit the wall of the outer casing. The optical signal is neither distorted nor dramatically weakened as it travels along the fibre, because the reflective casing absorbs none of the light from the core. This means that the light wave can travel much greater distances without losing much speed or clarity.



The so-called 'last mile' of the content delivery from the provider to the consumer will likely still be copper wire, rather than fibre-optic cable, negating some of its advantages.

DID YOU KNOW? Amazingly an optical fibre can carry 2.4 million phone calls simultaneously, while a single copper wire can carry just six phone calls.

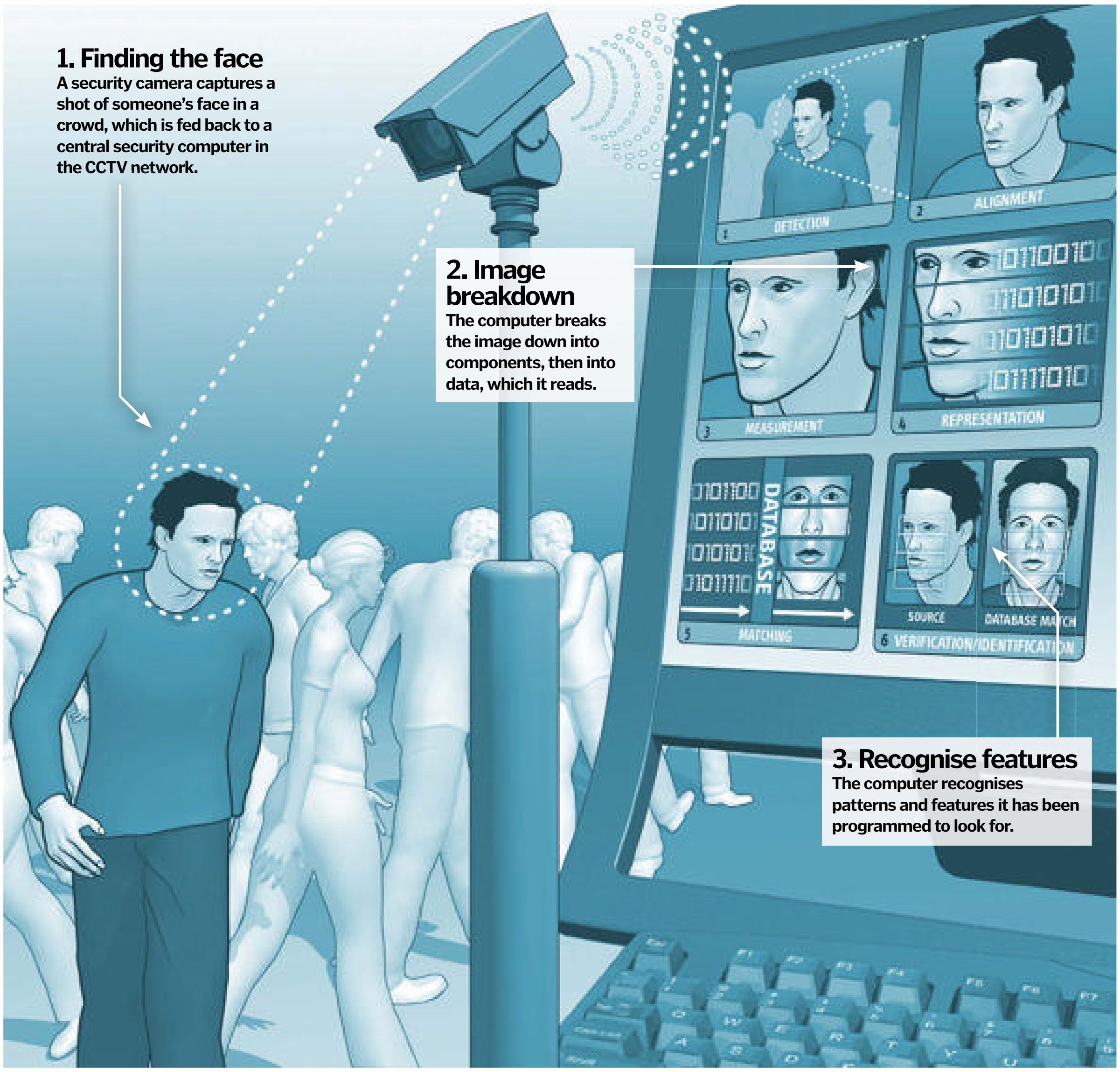
Facial recognition explained

Find out how a computer can pick you out from the crowd

Facial recognition is something that comes easily to humans – we learn it within weeks of birth – but it was a much harder feat to achieve with a computer. We recognise faces because we are, essentially, 'programmed' to do so by our evolutionary psychology. However, a computer – which is based on a structure of logical, mathematical principles – doesn't have the emotional input that allows us to recognise even a colon and an end-bracket as a smiley face.

To get a computer to recognise a face you have to program it to look for certain things. For a start it has to be able to distinguish between a human face and everything else. This is done by programming a piece of software to look for what are known as 'nodal points'. These statistics govern things like the common width of noses or the standard range of depth for eyes.

Once the software can recognise the basic concept of a face, it can be programmed to recognise certain people. Your camera may have a Face Recognition feature, which you have to initially set up, taking several pictures of people and tagging them by name. The software learns the measurements of the nodal points around their faces thus recognising them automatically.



1. Finding the face
A security camera captures a shot of someone's face in a crowd, which is fed back to a central security computer in the CCTV network.

2. Image breakdown
The computer breaks the image down into components, then into data, which it reads.

3. Recognise features
The computer recognises patterns and features it has been programmed to look for.

How a Universal Serial Bus works

A closer look at one of the most-used connections around

Universal Serial Bus (USB) is a technology specification used to connect computers with input/output peripherals. The specification consists of a male and female four-pin plug, with one pin used to transmit power (five-volt DC, 500-900mA), two pins to send or receive data and one as a ground.

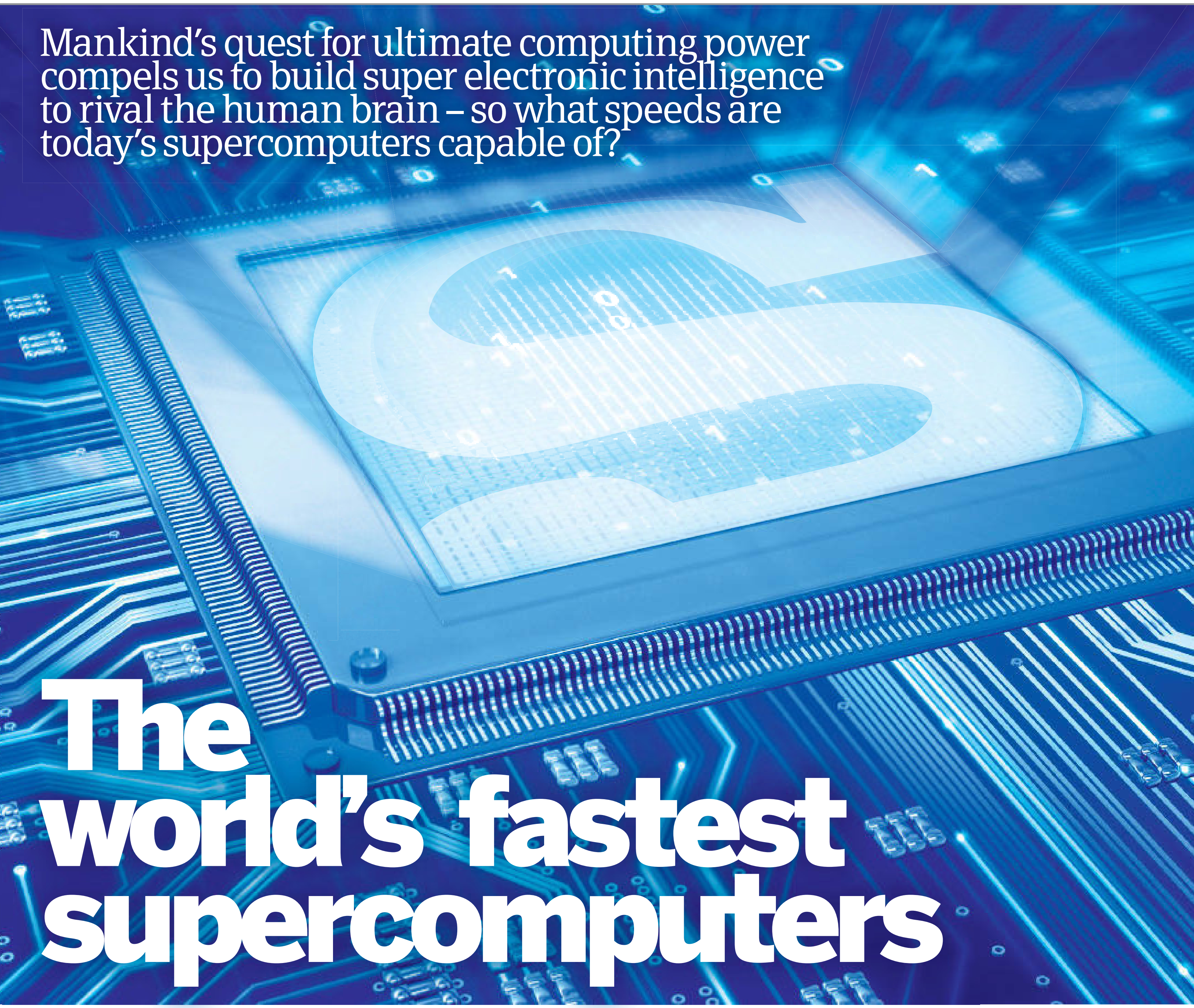
USB connections differ from the serial and parallel ports that they replaced, as they can transmit power and have increased – albeit non-guaranteed – data-transfer speeds.

When a USB connection is made between a host device and peripheral (such as a computer to keyboard), a set processing pattern begins. First a reset signal is sent from the host device to the peripheral to ascertain its data rate. Next the connected device's information is read by the host and, if supported, its drivers are transferred and installed so that proper communication can take place. Finally, under direct control from the host device, data transfer is begun, with files, data packets or media transferred from one to the other. Currently, over two billion USB devices are sold annually.

micro 4 GB
cruzer

The world's fastest supercomputers

Mankind's quest for ultimate computing power compels us to build super electronic intelligence to rival the human brain – so what speeds are today's supercomputers capable of?



Ever since Charles Babbage first proposed his 'Difference Engine' computer to the Royal Society in 1822, technology scientists have sought to create faster and more powerful computing machines. Our desire to process data more quickly and generally extract more 'juice' from our electronic devices has meant that we have been involved in a constant cycle of computing enhancements and augmentations.

As the race for home PC power reached what many people regard as its zenith during the Nineties, microprocessor manufacturers including Intel and AMD carried forward their research into increasingly thin silicon wafer technology in order to give us more power. Building CPU chips (or central processing units) that would run at ever-faster speeds meant that the scientists had to find a way of packing in more work-hungry transistors onto each layer of silicon. Eventually the silicon layers got so thin that home and business machines started using parallel processing techniques to perform multiple computations concurrently, which had in fact been employed within mainframes and supercomputers for many years.

So while your home laptop probably has most of the computing power that the supercomputers of the Sixties struggled to pump out, modern variants have been developed with astonishing levels of speed in terms of processing power. These machines can process algorithmic logic at speeds almost impossible for us to comprehend. But scientists and doctors still argue that however fast the hardware and software gets, it's still a cavernous gap away from the speed at which synaptic signals are transmitted around the human brain.

So how do these machines work in the real world? The power behind the supercomputer is the CPU, or as its often just called, the processor. This unit is prebuilt with an on-board degree in mathematics called an arithmetic logic unit (ALU), which it uses to perform mathematical operations including addition, subtraction, multiplication and division. Really

5 TOP FACTS
SUPERCOMPUTER APPLICATIONS

Tianhe-1A system

1 Residing at the National Supercomputer Center in Tianjin, China. The machine is used for Chinese weather forecasting and to help locate undersea oil fields.

Cray XT5 Jaguar

2 At the US Department of Energy's Oak Ridge Leadership Computing Facility, Tennessee, the Jaguar makes calculations to aid such complex research as protein folding.

Nebulae

3 This impressive beast draws its electrical lifeblood from the wall at China's National Supercomputing Centre in Shenzhen. It crunches numbers in the name of engineering.

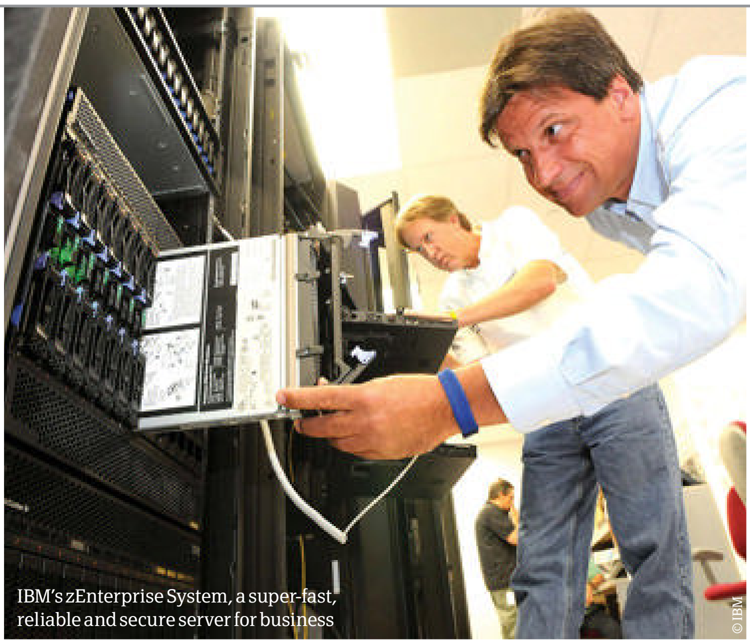
Tsubame 2.0

4 The Tokyo Institute of Technology's Tsubame 2.0 performs at 1.19 petaflops and helps provide GPU-based solutions for a variety of engineering research.

Hopper

5 Located in the US Department of Energy's National Energy Research Scientific Computing Center, Hopper helps power work in computational nanoscience for energy conversion.

DID YOU KNOW? New 'parallel' computing methods have been around for years in mainframes and high-performance computing

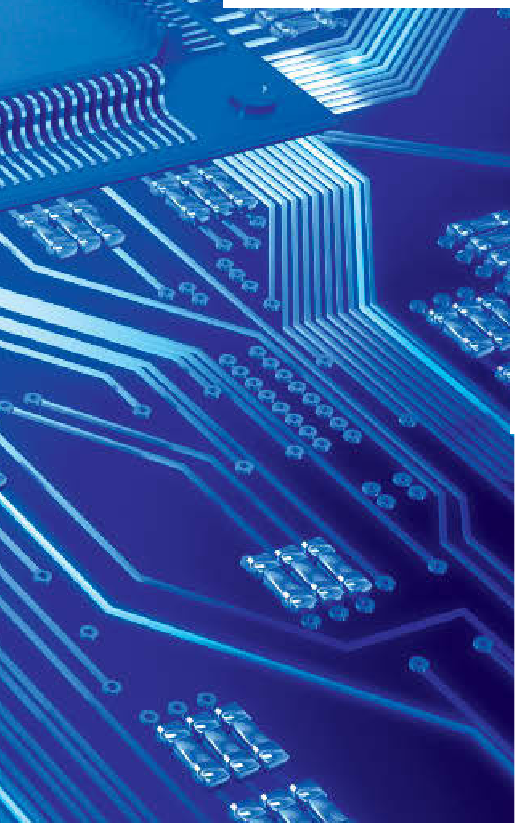


IBM's zEnterprise System, a super-fast, reliable and secure server for business

© IBM

Bluff your way in supercomputing

Do you know your parallel computing from your nanometre technology? If not then this glossary will help…

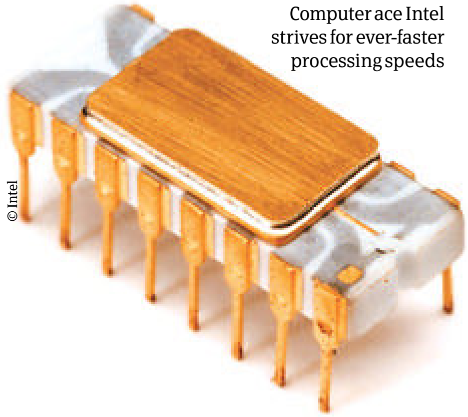


speedy modern processors of the type found in supercomputers can handle calculations using large floating-point numbers, which gives them incredible speed.

If you don't remember floating-point numbers from school, put simply these are numbers where the decimal point can be moved around to create additional numbers. By moving the decimal point around, more numbers can be created from a single set of digits – and the rest we can leave to the scientists. What we should know is that floating-point operations are crucial to supercomputers as the speed at which they can carry out calculations upon them give us our floating point operations per second (FLOPs) measure.

So where has the development of supercomputers brought us in terms of day-to-day technology usage? While many super machines are used for research projects, other machines are being employed by so-called cloud computing providers to build 'virtual' computing machines shared by multiple tenants across a network. It may sound complicated, but it's not really.

"There has always been a lot of jargon associated with supercomputing, computing clusters, computing grids and now we have differing definitions of cloud computing to contend with," says Ken Hertzler, vice president of product management at Platform Computing. "But essentially, cloud computing is very simple. It is a set of large-scale 'servers', which exist to 'host' your computing needs on a pay-per-use basis. It's a bit like throwing an extra log on the fire when it's snowing outside, ie the extra power is there when you need it. This is virtual computing in its plainest sense; much of the hardware and software exists at the cloud data centre – all you really need is a laptop." ▶



Computer ace Intel strives for ever-faster processing speeds

© Intel

Clusters are groups of computing resources that have been 'coupled' together with some intelligent software to enable them to work together.

Sounds complicated – but it's not. Your computer can do two (or more) things at once if it executes jobs into individual streams – in parallel.

Dedicated 'graphics processing units' are built specifically to handle software applications that need to handle so-called 'rich' graphics and on-screen 'rendering' of images.

Floating point operations per second is used as a measure of supercomputer performance to express how many floating-point numbers the machine can use to carry out algorithmic calculations inside, logically, one second.

A petaflop is a computer's ability to perform 1 quadrillion floating point operations per second.

A petabyte is equal to 1 quadrillion bytes – or 1,000 terabytes.

GPU PETABYTE
CLUSTERS FLOPS
PETAFLOP PARALLEL
HPC COMPUTING
TERABYTE PROCESSOR
MULTI-TENANT CORES
CPU NANOMETRE
VIRTUALISATION

The existence of more than one corporate user (or company) on a network using shared software and hardware resources.

The CPU or 'central processing unit' is commonly referred to as the 'brains of the computer'. In fact it is a set of integrated circuits that carry out the core 'instructions' needed for the computer to operate.

Virtualisation is the shared allocation of computing resources from a centralised network of data and processing power.

A terabyte is equal to 1,000 gigabytes – a measurement gauge that most of us will be familiar with.

The nanometre measurement denotes one billionth of a metre and is used in the microprocessor industry to detail the 'thinness' of the silicon wafers used to build a 'chip'.

HPC denotes the use of supercomputers and computing clusters to solve advanced mathematical problems at the petaflops level of processing.

Machines used to ship with no more than one processor core. Today, multiple core processors are built to reside side-by-side and produce more power.

If we plunge deeper into the supercomputing supernova we start to see where the real beasts reside; ie dedicated lumps of raw computing power that sit immobile on their indomitable data-driven haunches to carry out mankind's most complex computational desires. One such beast that most of us will have heard about is the supercomputer located on the French-Swiss border at CERN, which carries out the number crunching for the Large Hadron Collider. In fact, CERN's life force is monitored by something in excess of 2,500 clustered servers running the Linux operating system.

Because the Large Hadron Collider generates such massive volumes of data, the scientists need custom-built supercomputing power if they are to successfully analyse the subatomic particles that get bashed around the inside the Collider's seemingly endless miles of internal structure.

But this is still science, so how do supercomputers work in our world where we can see and feel their real effects and power? Computing giant IBM tried to show us evidence of the real power of its Deep Blue supercomputer in May of 1997 when it set the machine's logic to play a fascinating match with the reigning World Chess Champion, Garry Kasparov.

After beating every chess computer that IBM had developed for over a decade and a half, Kasparov was finally defeated by Deep Blue. Writing a number of years after suffering his defeat, Kasparov noted that Deep Blue was hardly what the supercomputing pioneers had initially dreamed of. "Instead of a computer that thought and played chess like a human, with human creativity and intuition, they got one that played like a machine, systematically evaluating 200 million possible moves on the chess board per second and winning with brute number-crunching force," said Kasparov.

This reality, of course, did not stop IBM using the win to great effect for publicity purposes and indeed the company has continued to label the research arm of its supercomputer business as 'Deep Computing' to this day. "Combining these [Deep Computing] capabilities with advances in algorithms, analytic methods, modelling and simulation, visualisation, data management and software infrastructures is enabling valuable scientific, engineering and business opportunities," says IBM.

With all the high-end big scale computing discussion, you may think that you personally don't impact the growth of supercomputers, right? Well, you'd be wrong. The average human is pushing the planet's data consumption rates up exponentially, every day. From every time you make a Google search, to every email, video, picture image or sound file you share. This is not just data, this is what the technologists call 'unstructured data'.

It's not a simple spreadsheet with ten numerical values in it that could be easily broken down and expressed in its most simple binary value state. This is complex-rich data with meta tags, embedded extras and when we start to also exchange this data on mobile devices on the go the situation multiplies tenfold. The era of the green screen is gone, the era of the supercomputer has only just begun.

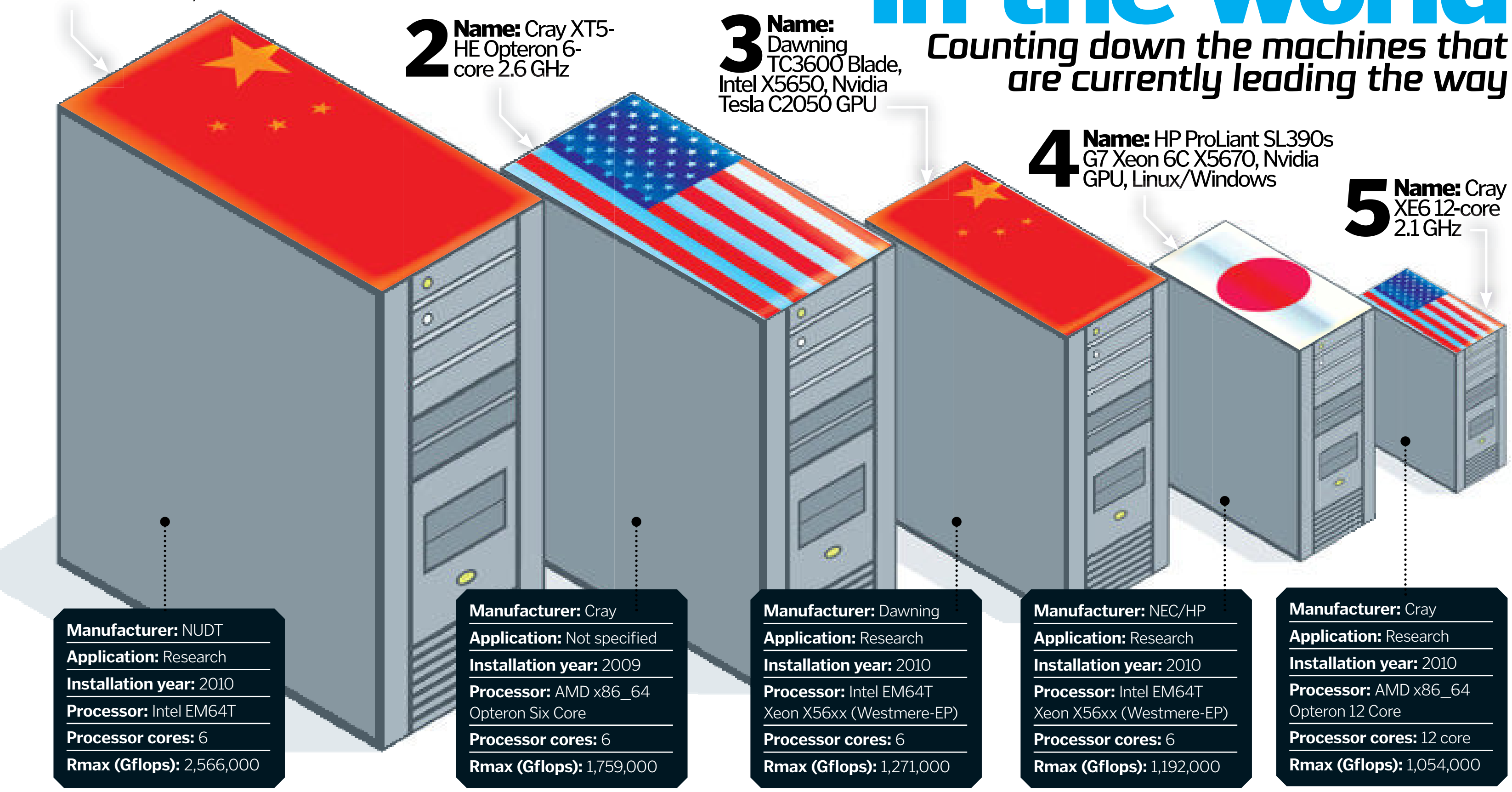
1990
Fastest that year:
NEC SX-3/44R
Manufacturer: NEC
Country: Tokyo, Japan
Power: 23.2 gigaflops
(that's 23,200 megaflops)

1980
Fastest that year:
CDC Cyber 205
Manufacturer: Control Data Corporation
Country: Canada
Power: 400 megaflops

1970
Fastest that year:
CDC 7600
Manufacturer: AEC-Lawrence Livermore National Laboratory
Country: California, USA
Power: 36 megaflops (remember that's 1,000 floating point operations per second)

Top 5 supercomputers in the world

Counting down the machines that are currently leading the way



1 **Name:** NUDT TH MPP, X5670 2.93GHz 6C, Nvidia GPU, FT-1000 8C

Manufacturer: NUDT
Application: Research
Installation year: 2010
Processor: Intel EM64T
Processor cores: 6
Rmax (Gflops): 2,566,000

2 **Name:** Cray XT5-HE Opteron 6-core 2.6 GHz

Manufacturer: Cray
Application: Not specified
Installation year: 2009
Processor: AMD x86_64 Opteron Six Core
Processor cores: 6
Rmax (Gflops): 1,759,000

3 **Name:** Dawning TC3600 Blade, Intel X5650, Nvidia Tesla C2050 GPU

Manufacturer: Dawning
Application: Research
Installation year: 2010
Processor: Intel EM64T Xeon X56xx (Westmere-EP)
Processor cores: 6
Rmax (Gflops): 1,271,000

4 **Name:** HP ProLiant SL390s G7 Xeon 6C X5670, Nvidia GPU, Linux/Windows

Manufacturer: NEC/HP
Application: Research
Installation year: 2010
Processor: Intel EM64T Xeon X56xx (Westmere-EP)
Processor cores: 6
Rmax (Gflops): 1,192,000

5 **Name:** Cray XE6 12-core 2.1 GHz

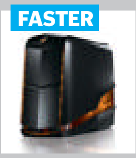
Manufacturer: Cray
Application: Research
Installation year: 2010
Processor: AMD x86_64 Opteron 12 Core
Processor cores: 12 core
Rmax (Gflops): 1,054,000

NOTE: Rmax is a maximum performance of a computer (measured in Gflop/s) achieved in the HPL benchmark

Head to Head COMMERCIAL HOME PCS

© Apple

1. Apple Mac Pro 12 Core
With up to 50 per cent greater performance than Apple's previous generation of high-end power-user machines, this is designed for the serious pro.



2. Alienware Aurora ALX
Aurora packs the power of the Area 51 models into a smaller shell without compromising on power. An Intel Core i7 920 Extreme processor offers a tasty 3.33GHz.

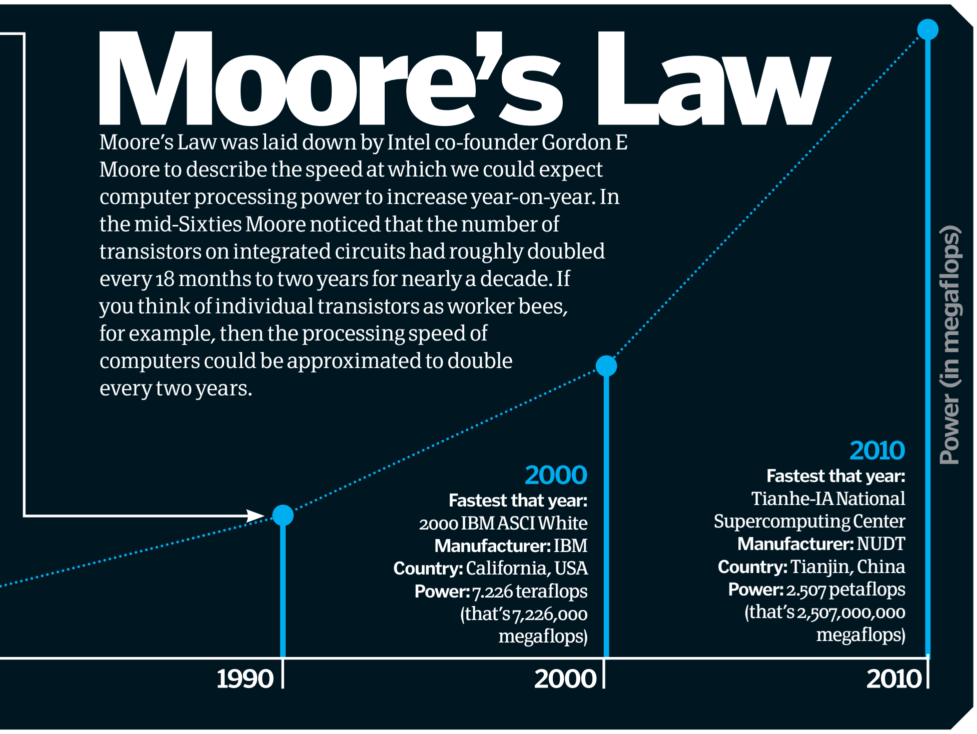
© www.originpc.com

3. Origin Genesis
This is an 'elite gaming PC' and pumping at its heart you'll find a Core i7-980X, which is Intel's six-core performance-focused processor and in this case it has been 'over-clocked' up to 4.3GHz.

DID YOU KNOW? *In 1981 Bill Gates was erroneously quoted as saying "640K of memory should be enough for anybody"*

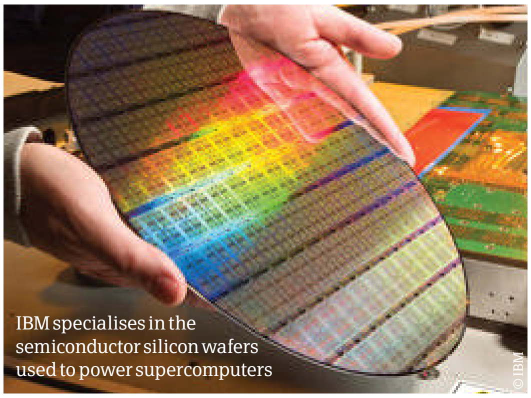
Moore's Law

Moore's Law was laid down by Intel co-founder Gordon E Moore to describe the speed at which we could expect computer processing power to increase year-on-year. In the mid-Sixties Moore noticed that the number of transistors on integrated circuits had roughly doubled every 18 months to two years for nearly a decade. If you think of individual transistors as worker bees, for example, then the processing speed of computers could be approximated to double every two years.



2000
Fastest that year: 2000 IBM ASCI White
Manufacturer: IBM
Country: California, USA
Power: 7.226 teraflops (that's 7,226,000 megaflops)

2010
Fastest that year: Tianhe-IA National Supercomputing Center
Manufacturer: NUDT
Country: Tianjin, China
Power: 2.507 petaflops (that's 2,507,000,000 megaflops)


IBM specialises in the semiconductor silicon wafers used to power supercomputers
© IBM

© IBM

Which countries are home to the most supercomputers?

This global map reveals in which countries you'll find the majority of the world's supercomputers, and of those countries which are home to the ten fastest…

US
How many: 274
The US is home to five out of the top ten speediest supercomputers. At 1,759 teraflops, America's fastest is the second quickest overall.

UK
How many: 25
The UK has no supercomputers in the top ten.

Germany
How many: 26
The ninth fastest supercomputer in the world is found in Germany and reaches 825.5 teraflops.

China
How many: 41
Home to the fastest supercomputer in the world at 2,566 teraflops.

France
How many: 26
France houses the sixth fastest supercomputer in the the top ten at 1,050 teraflops.

Japan
How many: 26
Number four in the top ten is found in Japan at 1,192 teraflops.

Just how much is a petabyte?

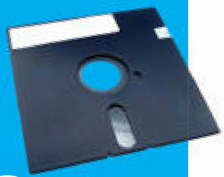
One day you may have to forget kilobytes, megabytes, gigabytes and even terabytes as we move to petabytes as our lowest denominator of data size and capacity. So just how big is a petabyte then?

1 petabyte equals…

1,000 terabytes
Okay, so you know your 500 gigabyte hard drive at home? That's half a terabyte. So a petabyte is 2,000 home computers with 500 gigabyte hard drives. More than you have room for at home, right?

1,000,000 gigabytes
One gigabyte holds around three hours of high-quality video, so one petabyte holds 3 million hours, and that's 342 years.

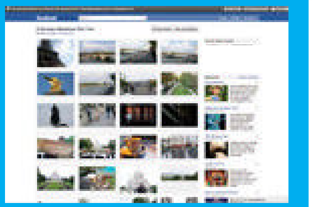
500 million old style floppy disks
This is roughly the same amount of data as processed by Google inside any one single hour of the day.



20 million filing cabinets
One petabyte holds approximately 20 million standard office issue metal four-door filing cabinets full of printed A4 text.

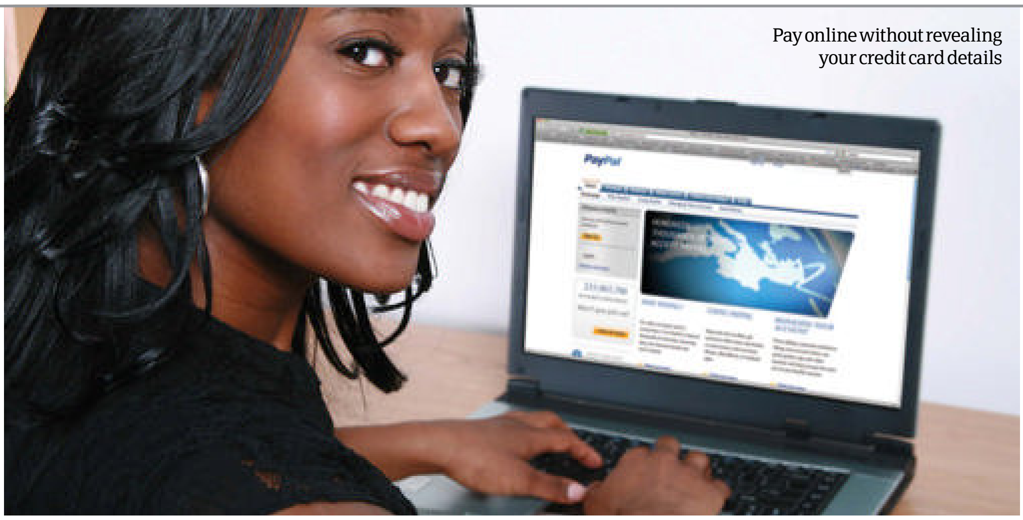
113,955 hours of HD video
One petabyte holds somewhere around 113,955 hours of HD-TV video – that's around 50,000 individual HD movies.

7 million Facebook photos



One petabyte holds approximately 7 million 25cm high Facebook-size webpage photos. If you laid those photos end to end that's roughly Land's End to John o'Groats by road if you stop at a few B&Bs along the way.

+ 50 petabytes: Entire written works of mankind
It has been estimated that 50 petabytes is enough data storage to hold the entire written works of mankind (in all languages).



Pay online without revealing your credit card details

PayPal

The technology behind these secure online payments

PayPal works by utilising thousands of separate servers running the Linux operating system, literal 'blocks' of servers that can be redistributed to perform different tasks in tandem with one another. These thousands of servers connect with an offline database of customer information to transfer data back and forth between payee and recipient. However, the servers don't share information with each other, so anyone trying to break into the system would have to scour the heavily encrypted servers one by one to piece together the relevant data. This separation of the servers allows PayPal to remain secure while quickly processing the millions of payments it receives, as it would be almost impossible to obtain access to the different servers simultaneously to gather data.

The process is best shown through a step-by-step transaction. When a product is bought, the buyer – who has supplied PayPal with their bank details – authorises a transaction via credit card or cheque to debit their account for the purchase price. This transaction is handled directly by PayPal, who contact the seller's bank, credit card association and card issuer, paying the various interchange fees necessary to process it. The seller's money is then deposited into a dedicated PayPal account. This process is mirrored for the merchant, but is processed on a completely separate server for security reasons. Finally, after a set period of time, the money is transferred to the buyer's account in another completely separate transaction across another server.

Jargon buster

Server

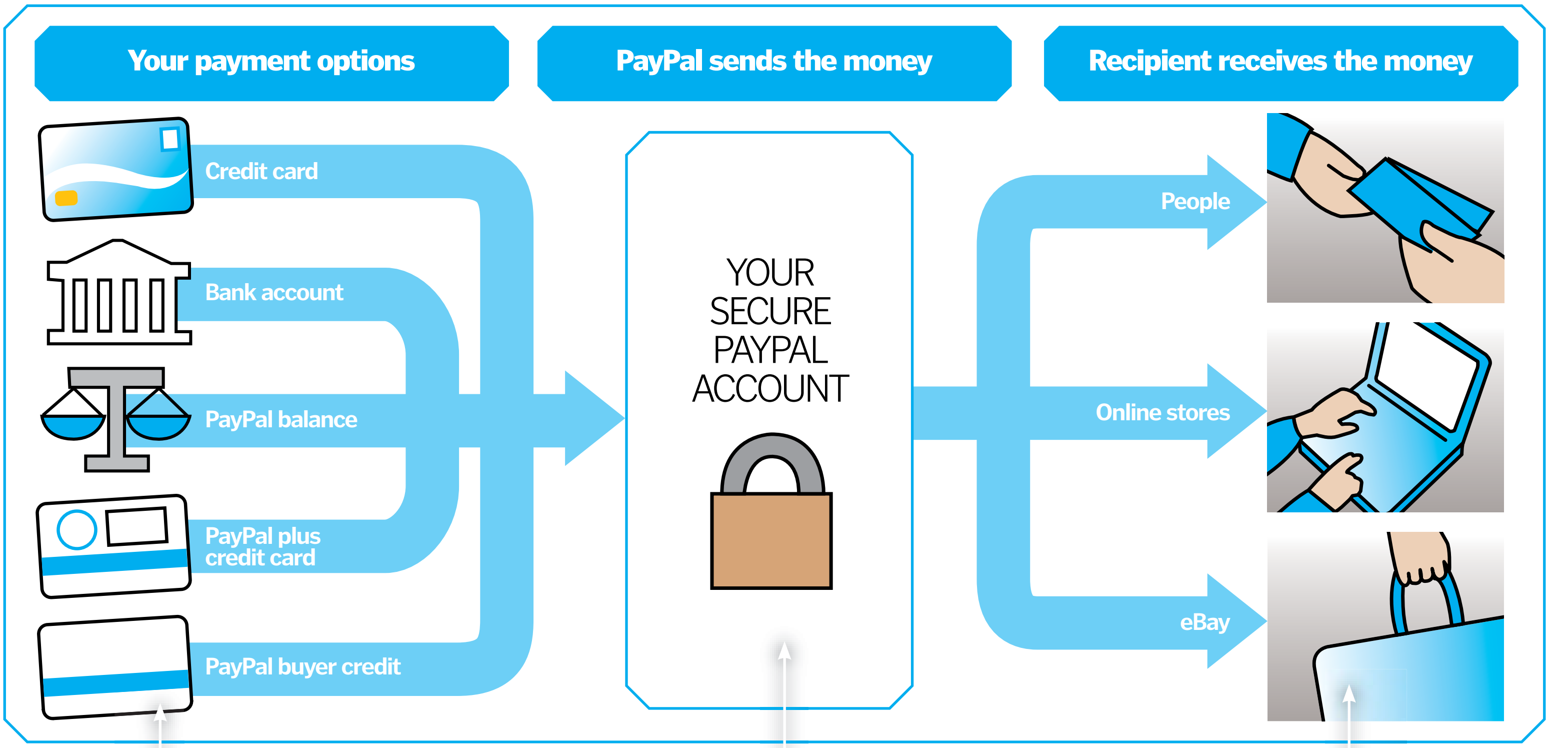
A server is a computer dedicated to linking other computers or electronic devices together, which in large companies tend to operate in banks (groups).

Interchange

Interchanges are small fees charged by banks and companies involved in a transaction, in order to facilitate their processing.

Linux

An operating system (like Windows or iOS) used extensively worldwide in servers and supercomputers, due to its speed and security.



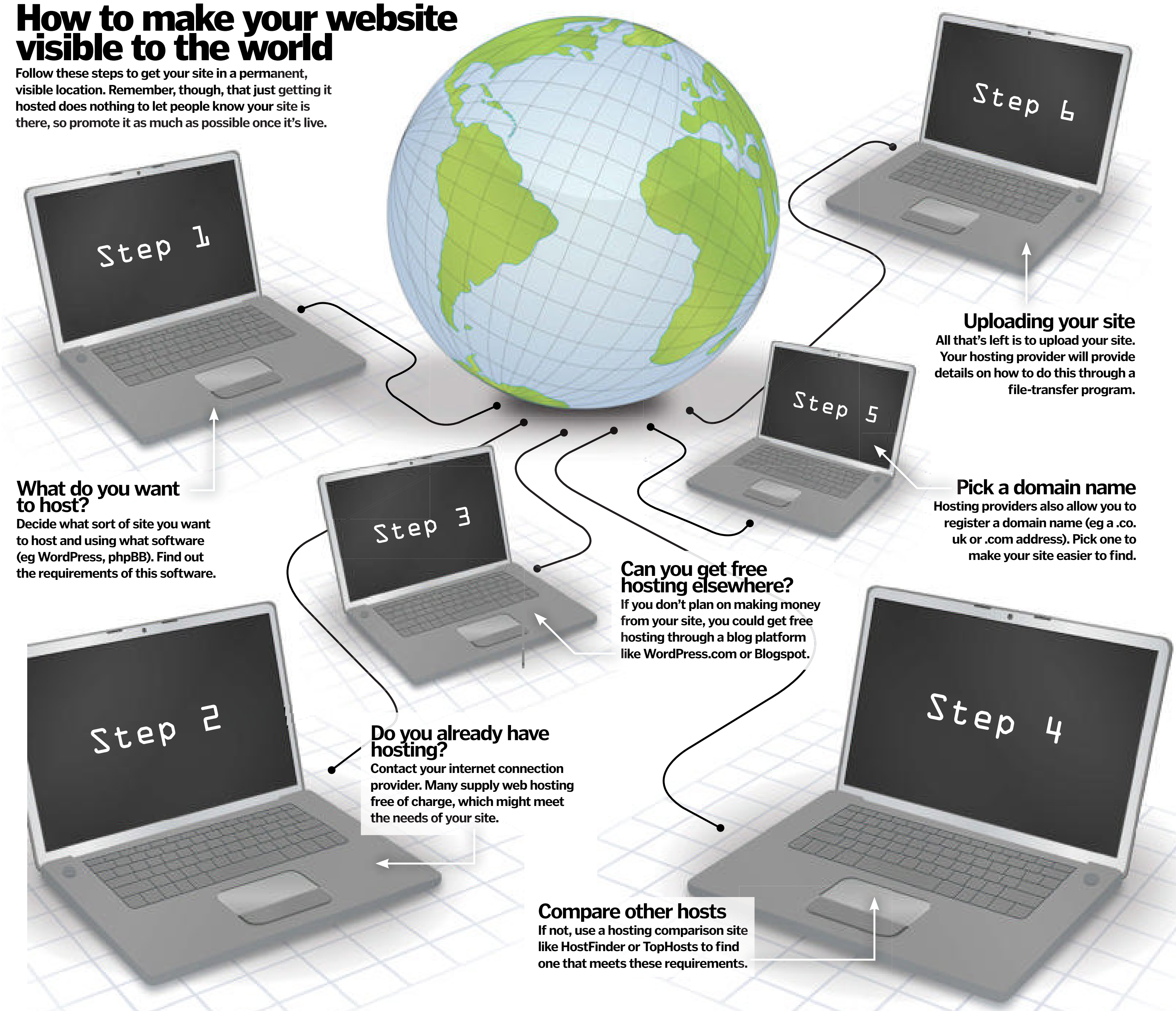
1. Method
PayPal accepts many different types of payment method, from cheque to credit card. The type of payment affects the amount of interchange fees that are paid and processing time.

2. Interest
PayPal makes money by accruing interest on banked payments, as well as direct fees charged according to an item's value.

3. Exchange
PayPal payments are not restricted just to online stores and auction houses, with people able to directly wire funds to any other person with an email address.

How to make your website visible to the world

Follow these steps to get your site in a permanent, visible location. Remember, though, that just getting it hosted does nothing to let people know your site is there, so promote it as much as possible once it's live.



What do you want to host?

Decide what sort of site you want to host and using what software (eg WordPress, phpBB). Find out the requirements of this software.

Do you already have hosting?

Contact your internet connection provider. Many supply web hosting free of charge, which might meet the needs of your site.

Can you get free hosting elsewhere?

If you don't plan on making money from your site, you could get free hosting through a blog platform like WordPress.com or Blogspot.

Compare other hosts

If not, use a hosting comparison site like HostFinder or TopHosts to find one that meets these requirements.

Pick a domain name

Hosting providers also allow you to register a domain name (eg a .co.uk or .com address). Pick one to make your site easier to find.

Uploading your site

All that's left is to upload your site. Your hosting provider will provide details on how to do this through a file-transfer program.

How web hosting works

Web-hosting companies cater for the world's websites, but what do they do?

Every time you visit your favourite website, you're in contact with a web server – a program that figures out what content you're asking to see, and then sends it to your browser. Any computer can act as a web server, but the trend is to have a company that runs servers that host your site for you.

Web servers need to be on all the time so visitors can access the site – hosting companies specialise in keeping servers running and connected to the internet 24 hours a day. It's also much cheaper for a hosting company to run one server that could potentially host hundreds of sites than it would be for each of those sites to be hosted privately. Finally, the hosting company takes a lot of the worry out of hosting a site by making sure their servers are secured to the highest standards.

Most of the world's websites use a 'virtual hosting' system. In this case, a server at a particular internet address holds many websites. All the domain names (the names in words that end with .com, for example) for those sites point to that one server. Whenever you visit a page, your browser makes a point of telling the server which domain name it used to find it, allowing it to figure out which of the thousands of pages on its disk to send back to you.

Social networks

Discover the technical side of the social media sites that keep us connected with friends around the world

At the heart of many social networking platforms, such as Facebook and the like, is a software tool called the Application Programming Interface (API). This enables multiple communities of users to create an open architecture for sharing data (including photos, tags, events and so on) between communities as well as other applications. Content created in one place can be posted and updated in numerous locations on the web, creating a web of dynamic information.

At the core of this web is a set of rules and specifications that the social network's software (ie the network's web pages that users interact with) can liaise with in order transmit and share information. In essence, the rules dictate the structure of the social web around – and accessible buy – a user, granting permissions and access, as well as dictating information relevant to them (their friend's photos, pages, and so on).

For the rules to work – certainly when they are operating based on HTML code (HyperText Markup Language, the building block code of any webpage) – each point on the social network's web must be represented as an 'object' with a unique id code. For example, on Facebook your profile page is an object, with a unique code. Therefore, if another user wishes to view your profile they must acquire that code to do so – as dictated by the network's rule-base – in order for the connection to take place. This is facilitated by Facebook's software interface, allowing that person to click on your profile link to fetch that object. This is also why people who have not been granted permission to access a person's full details (ie, they are not 'friends') cannot see that data. Their relationship on the social graph, as dictated by the API's rules, does not allow them to fetch that object, as they have not been granted an 'access token'.

Everything on a Facebook page – be that photos, events, news, comments or links – are classed not only as objects by the API, but are directly and indirectly connected by the social graph. Furthermore, there are various different types of connections for various objects, ranging from movie choices and audio/video tags through to groups and news feeds – each linked by the API's rules across the social graph (ie the map by which all users are connected).

Where Facebook's system gets really smart is in its utilisation of an object/connection ranking formula referred to as EdgeRank, an algorithm that charts all interaction between objects and ranks them accordingly. So, for example, if you have an event in your Facebook news feed (referred to as your 'wall') and a fellow user interacts with that object (ie, clicks its link, leaving a comment or a 'like' or 'dislike'), they create an 'Edge'.

Each Edge/interaction consists of three components vital to Facebook's algorithm: affinity, weight and time. Affinity is dictated by the frequency of interaction between two objects,

5 TOP FACTS
SOCIAL NETWORKING

Real estate

1 Social network giant Facebook is currently building a data centre in Oregon, USA, that measures 307,000 square feet; the scale of the building has doubled in the past year.

Followers

2 Pop star Lady Gaga currently holds the record for having the most Twitter followers, with over eight million people tracking her regular updates.

$50bn

3 Following investment from Goldman Sachs and a wealthy Russian investor, it was estimated that Facebook was worth a whopping amount of $50bn.

My decline

4 In the first half of 2010 it was estimated that visits to MySpace halved from 10 million to 5 million, as social networking rival Facebook grew in popularity.

Tweets

5 As of 1 January 2011, it was estimated that 110 million tweets were posted to Twitter every day from the 200 million registered users on the site.

DID YOU KNOW? *Facebook experiences roughly 2,000 photo uploads every second – that's just short of 173 million per day*

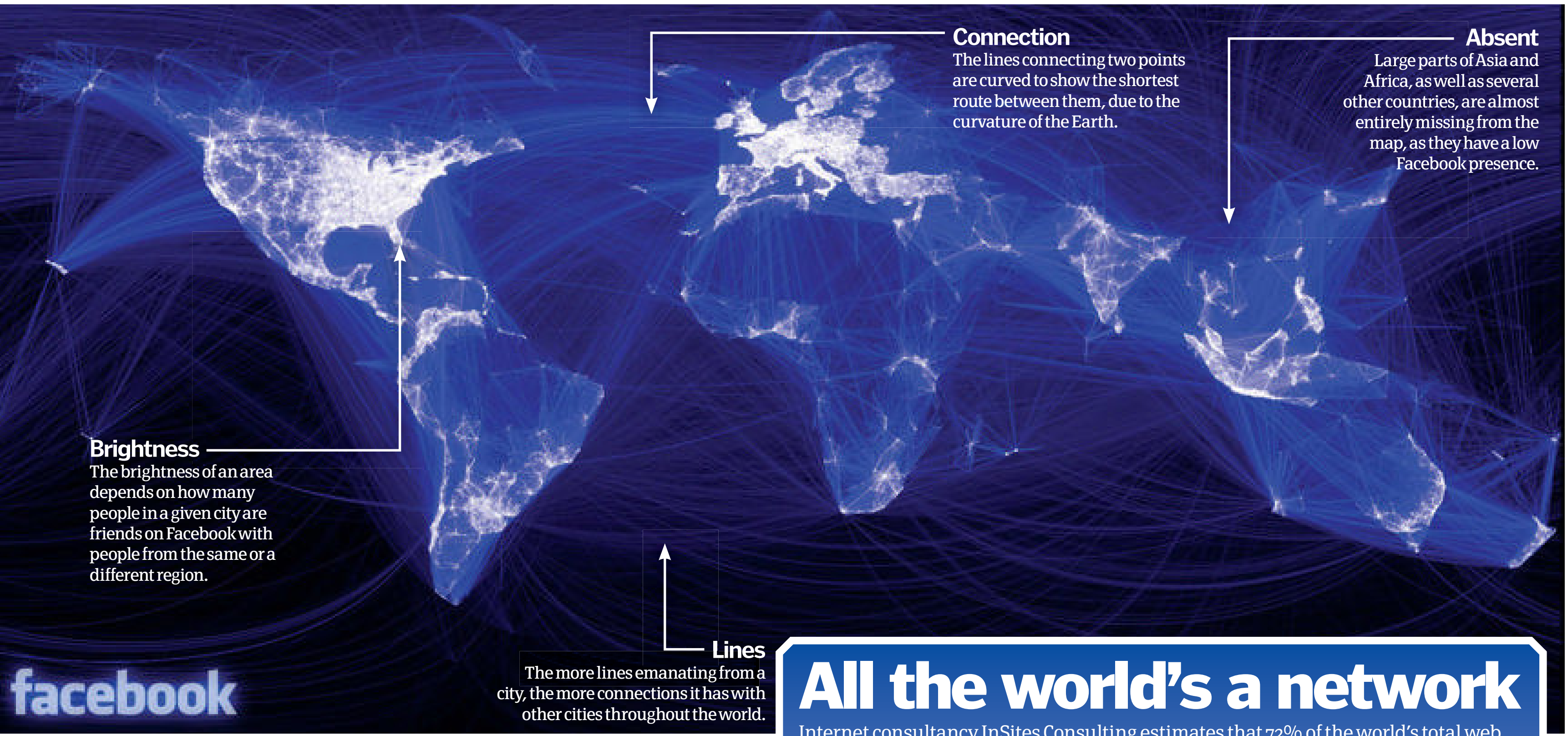
Facebook map

This map of the world was created by linking people on Facebook with their friends in other cities

Paul Butler, an intern at Facebook, created this map of the world using only the connections between friends on the social network. Without using the map of the world as a template, the connections gradually began to show the borders of countries, continents and coastal lines.

The effect works by a sample of ten million random pairs of friends being taken from the Facebook database. Linking them to each other's city and calculating the number of friends between those cities gives a brightness intensity of how many connections a specific region has to another, some intercontinental and some within the same country.

The outline of the world shows the connections between users of the social network, giving a clearly identifiable map of Earth. Countries such as China and Russia are almost invisible, with a very small Facebook userbase.



Connection
The lines connecting two points are curved to show the shortest route between them, due to the curvature of the Earth.

Absent
Large parts of Asia and Africa, as well as several other countries, are almost entirely missing from the map, as they have a low Facebook presence.

Brightness
The brightness of an area depends on how many people in a given city are friends on Facebook with people from the same or a different region.

Lines
The more lines emanating from a city, the more connections it has with other cities throughout the world.

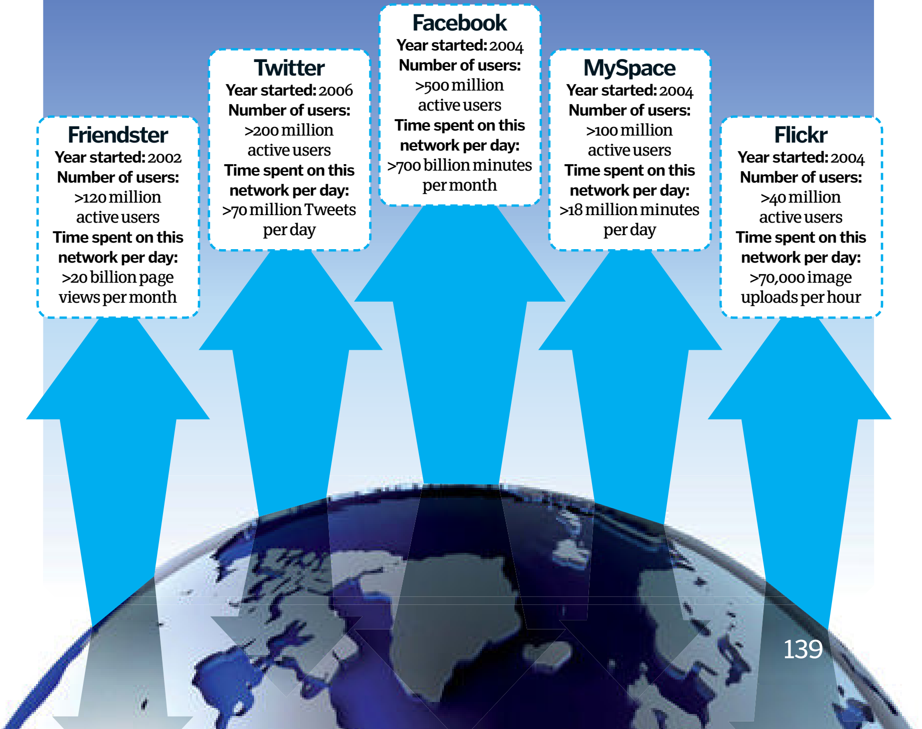
"The Application Programming Interface dictates the rules and structure of the social graph"

characterised by two close friends who leave daily comments on each other's wall. Weight refers to the level of interaction, with comments and direct messages carrying more significance than a poke. Finally, the time factor of an interaction degrades over time, so if a user interacted with another three months ago, it is less significant than if they did so yesterday. These three components are then multiplied by the ranking system to produce that object's EdgeRank or, simply, its relevance to any person on the social graph.

As well as using social network API's and analysis software, Facebook and social sites like Twitter, YouTube and Zynga also use an intelligent memory management system called memcaching to offer smoother user-side accessing and fetching of any object (data is stored in vast data centres). Memcaching is a kind of 'balancing system' where commonly used data is stored in a user's PC's fast-to-access RAM memory, to reduce the number of times the site needs to call on the back end data centre.

All the world's a network

Internet consultancy InSites Consulting estimates that 72% of the world's total web user base are a member of a social network. If we match this stat with InternetWorldStats.com's estimation of the total number of worldwide web users at 1,966,514,816, we can say that 1,415,890,668 of us belong to the planet's social networking community. InSites also estimates that most of us belong to an average of two networks, so the total social network 'network' may be as high as 3 billion.



Friendster
Year started: 2002
Number of users: >120 million active users
Time spent on this network per day: >20 billion page views per month

Twitter
Year started: 2006
Number of users: >200 million active users
Time spent on this network per day: >70 million Tweets per day

Facebook
Year started: 2004
Number of users: >500 million active users
Time spent on this network per day: >700 billion minutes per month

MySpace
Year started: 2004
Number of users: >100 million active users
Time spent on this network per day: >18 million minutes per day

Flickr
Year started: 2004
Number of users: >40 million active users
Time spent on this network per day: >70,000 image uploads per hour

Anatomy of a social network

Home Your Profile My Account Privacy

The major elements of a social media site and how they work

Search

How It Works
Edit My Profile

- News Feed
- Messaging
- 25 Events / Calendar
- Friends List

User profiles

When social networking sites want to share profile information between each other and connect, they rely on the fact that the same 'type' of data is used by convention across different services or sites. But how can one system talk to another when it may be programmed in a different computer language and different core operating system?

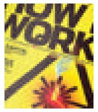
Much of the common data that is shared (eg, your name, your contacts and your favourites) will be exchanged as a result of what is known as syntactic analysis, or as it is commonly known in computer science, 'parsing'.

Not as complex as it sounds, parsing is the division of data into smaller parts so that it can be formatted into 'tuples', which are individual values in a table. For example, the address Flat 59, Richmond Hill Gate, Bournemouth, UK could be labelled as number, road name, city and country. By collating this data, Facebook is able to create a map of people within a specific network and link them together.

Twitter

They may seem similar, but the differences between Twitter and the status updates on Facebook are more than apparent when you take a look at the framework of each website. Twitter employs the use of a programming language known as Ruby On Rails (RoR) used by many large websites. It allows Twitter to quickly handle the constant requests it receives from users, as millions of posts are 'Tweeted' every hour. RoR simplifies multiple codes into easy applications, handling the front end of the site, the web layout itself.

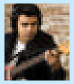
Twitter also employs the use of Scala, another programming language which supports the back end of the website. While RoR is used to adapt to the constant Tweets, Scala supports the website's servers and keeps the general framework ticking over. It handles the vast number of Tweets regularly sent to the website, and interacts with the information stored at Twitter's own data centre.



Howitworksmag

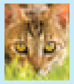
Posting our status here allows other users to comment and 'like' our status

10 minutes ago - Like - Comment



Grabbing attention - A user can view posts chronologically or by popularity on the 'Most Recent' and 'Top News' tabs

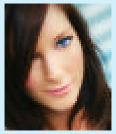
9 minutes ago - Like



Popularity contest - The more closely connected you are to somebody, the higher their post features in your 'Top News'

6 minutes ago - Like

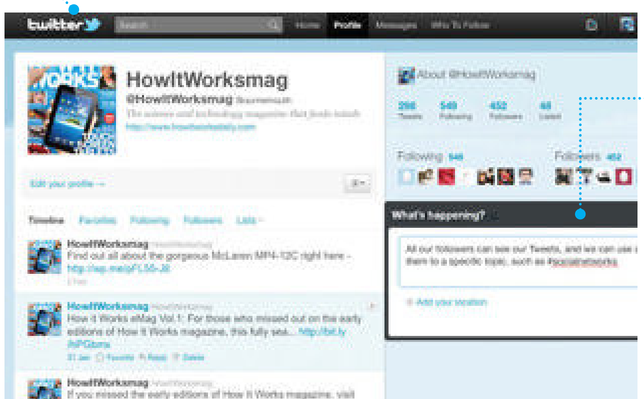
Write a comment...



Sarah's images

Images, videos and textual information are stored in data centres

10 minutes ago - Like - Comment



HowItWorksmag
Find out all about the gorgeous McLaren MP4-12C right here -

HowItWorksmag
How it Works eMag Vol 1: For those who missed out on the early editions of How It Works magazine, this fully sea...

HowItWorksmag
If you missed the early editions of How It Works magazine, visit

All our followers can see our Tweets, and we can use them to a specific topic, such as #socialnetworks

Updates

Twitter users do not see the most popular posts by others, rather just the most recent.

Trending

If a particular topic is garnering a lot of attention, through use of tools such as hashtags, which appear in the search engines, it will appear in the Trends section.

News feeds

Social networks use mathematical algorithms to dictate the relevance of any news story by assigning them a rank. A news story's rank is usually dictated by its affinity to a user – ie, is it an event planned by their close friend? – its weight, such as whether the user was mentioned in the news story, and chronological timeframe, with older stories being less worthy. On social networks such as MySpace and Facebook, news feeds are connected to almost every aspect of a user's profile, with even distant, third-hand connections (such as a friend of a friend commenting on a picture including the user) being mapped on the service's social graph.

Pokes

Simon Gladstone – Poke back
Beatrice Smalling – Poke back

Connections are key

Every action between users on Facebook further intensifies the connection two friends have with one another. This allows Facebook to tailor events, news and status updates to specific friends depending on who or what they have the most interactions with. For example, 'poking' a friend or accepting an invite to an event will show your affinity to them, strengthening the connection, and the stronger your Facebook friendship becomes the more Facebook will link the two of you in future.

Data handling

Due to the large quantity of uploaded information by users, such as videos, pictures and text, social networks require large amounts of storage and processing power. Large-scale industrial data centres are commonly used to store heavy data such as videos – as can be seen in the 307,000 square feet centre being currently built by Facebook in Oregon, US – while cloud-based networks (location-independent shared servers) are increasingly being used to handle lighter material. Banks of super-fast servers are used to maintain a fast and stable connection between the software and the remote data. In addition, to minimise the footprint of any piece of stored data, many social networks feature conversion software code built into the user interface, to ensure overly large files are not uploaded and those that are are optimised for the web.

Facebook, on the other hand, largely relies on PHP, a general scripting language that is fairly unsimplified. It uses specific lines of code, similar to HTML, to perform a particular request. This difference allows Twitter to operate quicker, as it relies on a constant flow of Tweets, whereas Facebook focuses more on the storing and accessibility of 'Profiles' and connections between friends.

Social networking on the move

User interface

Dedicated, optimised software interfaces allow social networks to be accessed efficiently.

Fetch and retrieve

Increased bandwidth enables remote content to be shared or downloaded quickly.

Real-time

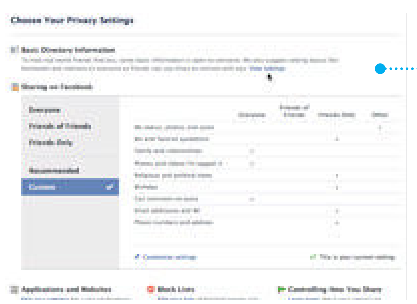
Always-on connections allow real-time status and profile updates.

Chat services

Messaging chat services have been around since the earliest Bulletin Board Services (BBS) in the early Seventies, as a precursor to email. Social networking sites have taken advantage of improved broadband connections to allow users to be able to chat in real-time.

Individual Facebook servers queue a user's messages and send them into their web browser via a programming language known as Erlang. This regularly deletes old chat messages and constantly updates the chat window but, when the user minimises the live conversation, Erlang will 'sleep' (work slower) until the user reactivates the window.

Chat (online) Friends: 5

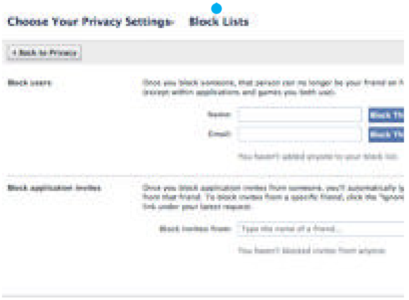


Everybody's changing

Each user can tailor their privacy settings to deny access.

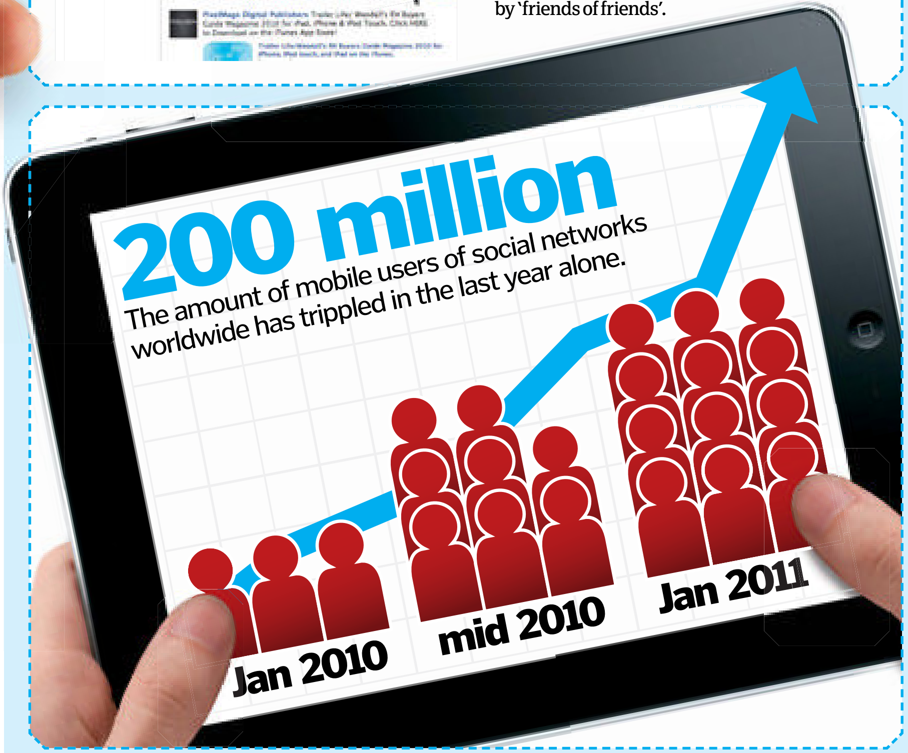
Blocking

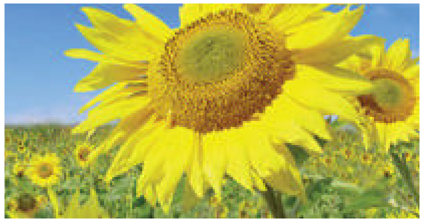
You can block specific users who may be trying to gain sensitive information.



Posts

Only people you've befriended will usually be able to see your status updates and profile, unless your settings allow them to be viewed by 'friends of friends'.





In a relationship?

This Valentine's Day, surprise your loved one with a beautiful hand-delivered bouquet from Flowers Forever.

MySpace

Many other social networks use a similar underlying framework to that of Facebook to provide an interactive environment for their users. MySpace, one of the most popular social networking sites on the internet, handles its large volume of traffic by redirecting page requests through an UltraDNS system, which accesses a large volume of storage and application servers upon which the website is based.

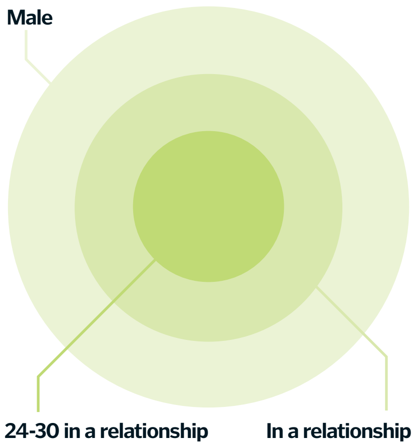
Like Facebook, MySpace allows users to create a hub of friends with whom they can share information and send messages. The difference, however, is that each user profile on MySpace is its own individual webpage, usually the web address followed by the person's username (for example, **www.myspace.com/howitworksmag**), allowing anyone on the internet to have access to their profile. Facebook, on the other hand, stores each profile within the website, and only members who are logged in can view them.

Intelligent adverts

Specific advertisements can be tailored to a user's personal data using relational database management systems, which act as servers and provide multi-user access to a number of databases. Using programs such as Google AdWords, advertisers can examine statistics relating to how users came to click on a particular website. The company knows how users used a particular search engine result, or paid for an advertisement to get to a site. It can then also examine how many people 'convert' from visiting a website's initial 'landing page' to become spending customers for a particular service.

Google has built new mechanics into web search that enables advertisers to target people who are searching for their product. Tailoring advertisements to the search terms that people use on Google and then sending visitors to the right page on a site means that users get to see the content they've searched for and website owners keep visitors for longer. Social networking portals allow advertisers to target people based on age, profile, marital status and preferences, making them increasingly commercially focused.

Targeting demographics



DID YOU KNOW?

DID YOU KNOW? *If Facebook were a country it would be the third most populated place on the planet behind India and China*

One for the album

More than 100 million photos are uploaded to Facebook every day and 99 per cent of people using Facebook have uploaded at least one photo. People celebrated New Year 2010 on Facebook by uploading a record 750 million photos over that weekend.

HOW IT WORKS

GADGETS

The coolest kit explained

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The best way to see who's telling the truth

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Get in closer with these nifty camera devices

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Inside the device that changed the world

Touch-screen tablets

SAMSUNG
9:02 AM
Phone
Readers Hub
Navigation
Camera
Places
Music
Video
Calendar
Thinkfree
Market
Browser
Applications
Email

© Samsung

Map
List
Distance: 48m
GALAXY Cafe

The world at your fingertips… and it's not too far from the truth!

© Samsung

5 TOP FACTS
TABLET PCS

Speed
1 Tablets work using processors that are on average two thirds slower than laptops, but they are still faster because they do not have to power CD drives and hardware keyboards.

Apps
2 Some apps are very similar to popular desktop titles, but often cost very little. With tablets selling by the million, developers can make their money by volume.

Multi-tasking
3 Multi-tasking on tablets is achieved by freezing apps when they are not in use, therefore freeing up precious memory for the currently running apps.

Voice
4 Tablets aren't made for voice calling, but Skype and other services let you use Voice Over IP as long as wireless data is available. A phone's still needed for general calling.

Growth
5 The growth of tablet sales is now starting to impact netbook and laptop sales with some believing that the tablet will dominate the entire computer market in the future.

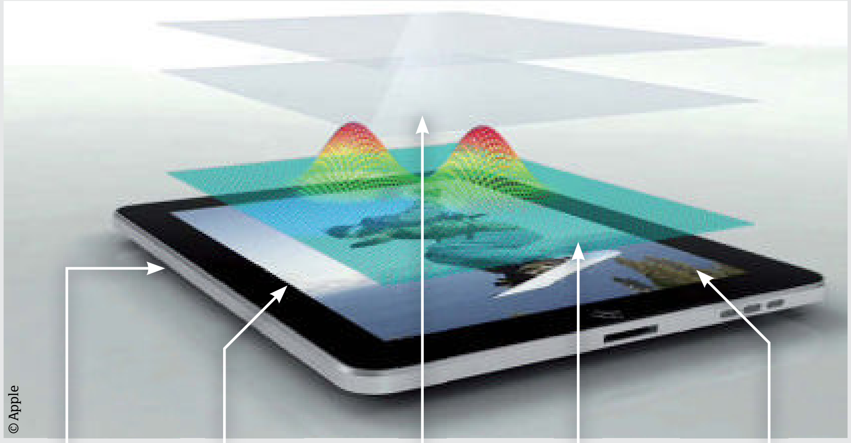
DID YOU KNOW? *Tablets are independent, but the iPad needs to be hooked up to a desktop computer on first use for it to work*

Tablets are less powerful than laptops, but can be more useful. Find out how they work and what they can do for you

A tablet is a cut-down version of a laptop. Besides having no physical keyboard, they also use operating systems designed to allow instant online access and an environment closer to the smartphone in design than a desktop operating system. Their great advantage is portability alongside battery lives that can reach up to ten hours, which makes them ideal to work on when out and about or to play on when on a long-distance flight.

Apple brought the tablet form to the attention of the world with the iPad in 2010 and this contrasted greatly with the previous failed efforts of Microsoft to make Windows fit this form factor. They are technically much less powerful than laptops, but this is ironically their biggest advantage. By focusing on allowing the user to consume and create in the simplest of ways they take away most of the maintenance involved in running a standard laptop and still manage to let you do everything you want to via cheap third-party apps. This also makes them faster than laptops for most tasks.

The Apple iPad and Samsung Galaxy Tab are currently the most powerful tablets available, but that will no doubt change in the very near future.


© Apple

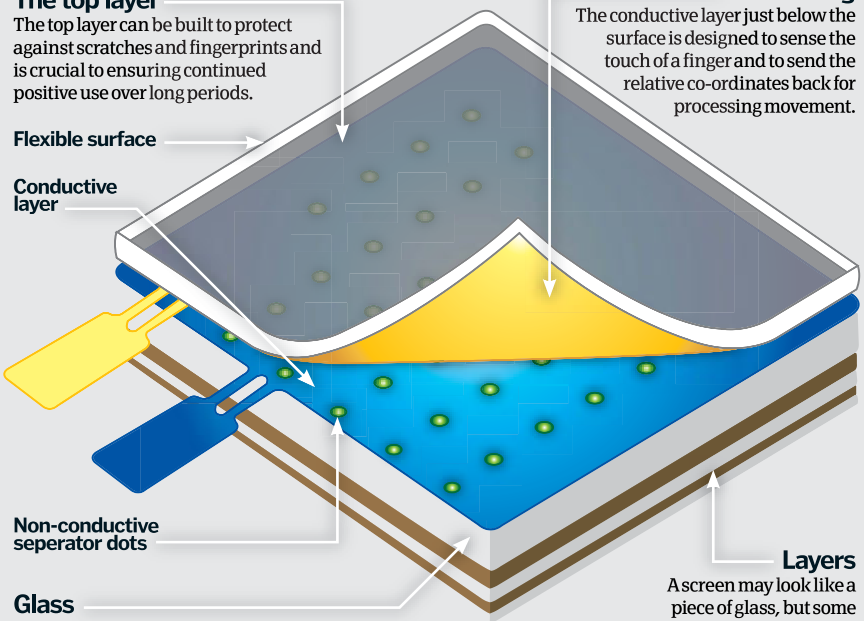
Movement
An accelerometer is built into the device which senses the orientation that it is being held at.

Flush
Most screens are built to be flush to the surround to allow navigation and touch all the way to each edge.

Protection
A protective layer is applied to the screen which is made from materials resistant to scratches.

Touch
The capacitive technology reads the electrical current from a finger to analyse placement.

Resolution
The iPad has a screen resolution of 1024x768 pixels. This isn't that high, but results are impressive.



The top layer
The top layer can be built to protect against scratches and fingerprints and is crucial to ensuring continued positive use over long periods.

Conducting
The conductive layer just below the surface is designed to sense the touch of a finger and to send the relative co-ordinates back for processing movement.

Flexible surface

Conductive layer

Non-conductive seperator dots

Glass
The glass layer is by far the thickest part of the screen, but is the least advanced. All of the clever stuff happens elsewhere.

Layers
A screen may look like a piece of glass, but some employ a multitude of layers to achieve the desired touch and viewing performance.

How does the screen work?

Capacitive screens, which the iPad and most high-end tablets use, are designed only to work with objects that are conductive such as fingers. This has the advantage of making them feel extremely natural in use. However, you do lose the preciseness of a stylus. The technology can sense the exact movement of a finger and when more than one finger is used it can determine the distance between them and the range of movement to accomplish tasks such as rotating or pinching and zooming photos.

You may be surprised to know that these screens carry an electrical charge, which is disrupted by your finger because it carries a different charge. This is how the conductive layer just below the surface can work out where the fingers are placed. A special coating is often applied to the screen, which resists scratches and fingerprints and is so thin that it's not viewable by the human eye. In-plane switching can also be employed to increase viewing angles by decreasing the amount of scattered light across the screen, allowing you to almost view text and images when holding the screen at a 90° angle to your eyes.

SAMSUNG
Layers
5th Avenue, New York

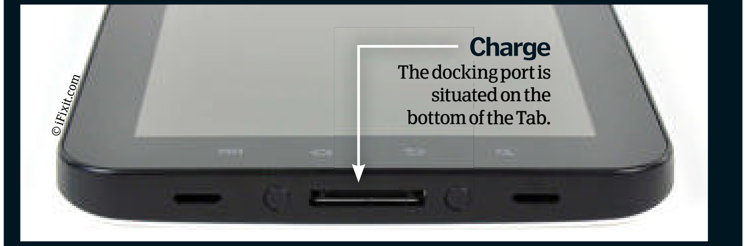
How does it connect to the internet?

Tablets connect to the internet in two ways: Wi-Fi and in some cases 3G. Wi-Fi is a lot quicker, but has to rely on the proximity of a router or a public hotspot. If a tablet has 3G capability, it will also require a suitable data plan to allow access anywhere. These can be expensive, but the setup does offer an advantage few laptops have which is almost universal internet connectivity. The efficiency of the operating systems and browsers, which were originally designed for slower smartphones, means that they run very quickly provided 3G coverage is available.

© Apple

Tablet hardware

Tablets are almost always closed systems that allow little upgrading of the internal parts. Some have expansion card slots to increase the available storage and there are accessories available such as external hardware keyboards and desk chargers, but on the whole they are designed to be used as they come out of the box. They do not have CD drives or USB ports because mechanical media can slow down overall performance whereas the flash-based memory inside a tablet is extremely fast. This also enables them to run more smoothly and quicker than laptops and desktops with better specifications. Many can be attached to a TV for video playback, which is achieved via the small built-in graphics processors. On the outside they are built to last with either aluminium or strengthened plastic used to house the otherwise fragile internals. The key to a tablet's speed and strength is the lack of moving parts, which also makes them extremely reliable.


Charge
The docking port is situated on the bottom of the Tab.

© iFixit.com

Tablet software

ebY
f
Tuesday
9

Almost all current tablets run the Android operating system which was designed for smartphones. The iPad runs iOS which Apple also uses on the iPhone, and they both rely on third-party apps to offer flexibility and these can be installed in seconds by downloading them from iTunes or the Android Market. Once installed they act in solitude with some clever programming enabling them to take advantage of specific hardware functions. They are not compatible with each other, but the larger publishers are supporting both operating systems with the same titles. Apple produces Pages and Numbers for the iPad which gives full Office document editing and there are also a number of Office apps available for Android tablets. Magazines are becoming a popular genre in the tablet world with the iPad offering more titles than the rest.

NEED FOR SPEED SHIFT

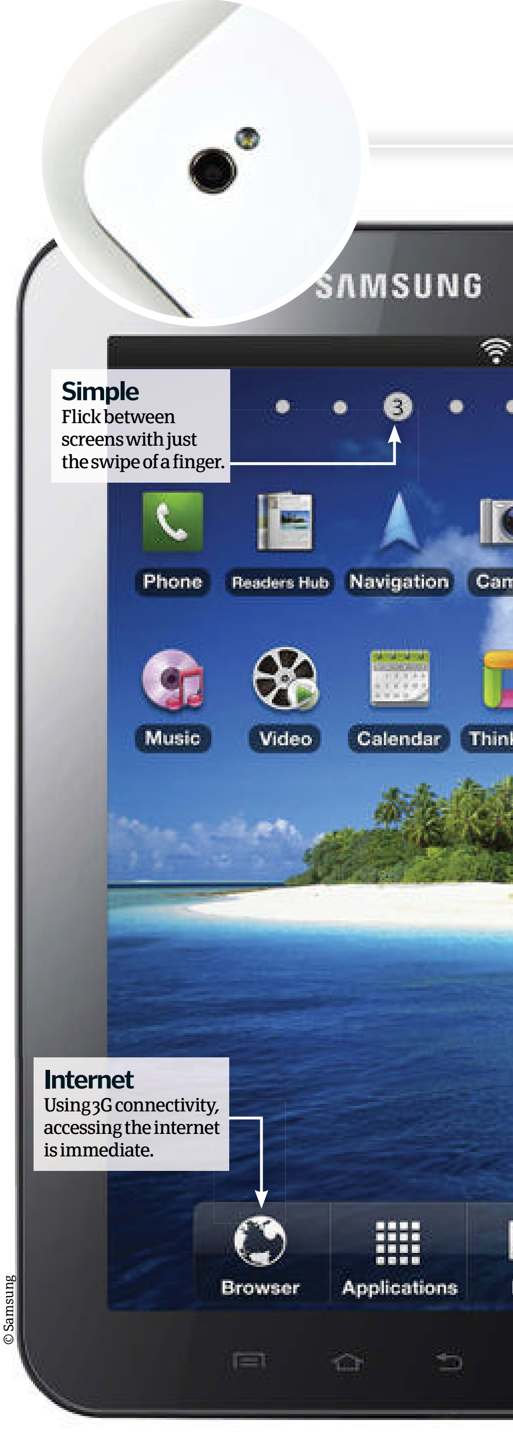
© Apple

What's inside the Samsung Galaxy Tab?

How does the flagship Android tablet manage to do so much in such a small space?

It would be easy to think of the Galaxy Tab as a very large Android smartphone, but that would be to ignore the thought that Samsung has put into designing the product. Designing a small tablet that still offers a usable experience is not easy, but some clever technology has been squeezed in to enable this to happen. The seven-inch super TFT screen has been designed by aligning the molecules of the liquid crystal to a perfect parallel, which allows for a wide viewing angle up to 170 degrees. This technology, while not new, is also power efficient which helps the battery produce up to seven hours of video playback on one single charge. This is backed up by the 1GHz Hummingbird processor which uses incredibly close placement of the circuitry on board to increase clock speeds resulting in minimal power drain. The inclusion of an HSDPA chip produces a mobile data speed of up to 7.2Mbps to rival many home broadband connections and the Broadcom chip takes care of Wi-Fi and Bluetooth enabling almost constant connections to the outside world.

The built-in gyroscopic sensor is able to sense exactly how the Tab is being held by sensing the exact position of a tiny vibrating object in relation to the X, Y and Z axes. This is particularly useful for advanced gaming and augmented reality apps which are designed to use this technology wherever possible. The front and rear cameras are not well specified, but are useful for snapshots or for video calling which utilises the front camera and the HSDPA or Wi-Fi connectivity. There is a lot of advanced technology squeezed into the Galaxy Tab, but it still remains light at only 380 grams. It is also half the weight of an iPad thanks to the plastic outer shell that has been used to cover the multitude of components. It may not look classy and is a very low tech material, but it certainly helps reduce the overall weight of this flagship tablet.



Simple
Flick between screens with just the swipe of a finger.

Internet
Using 3G connectivity, accessing the internet is immediate.

© Samsung

SMALLEST
© Dell

1. Dell Streak

Is it a big smartphone or a small tablet? Opinion seems to be divided over the five-inch screen form factor at this time.

IN THE MIDDLE
© Samsung

2. Samsung Galaxy Tab

The Tab uses the seven-inch screen form factor which aims to offer a tablet experience while maintaining portability.

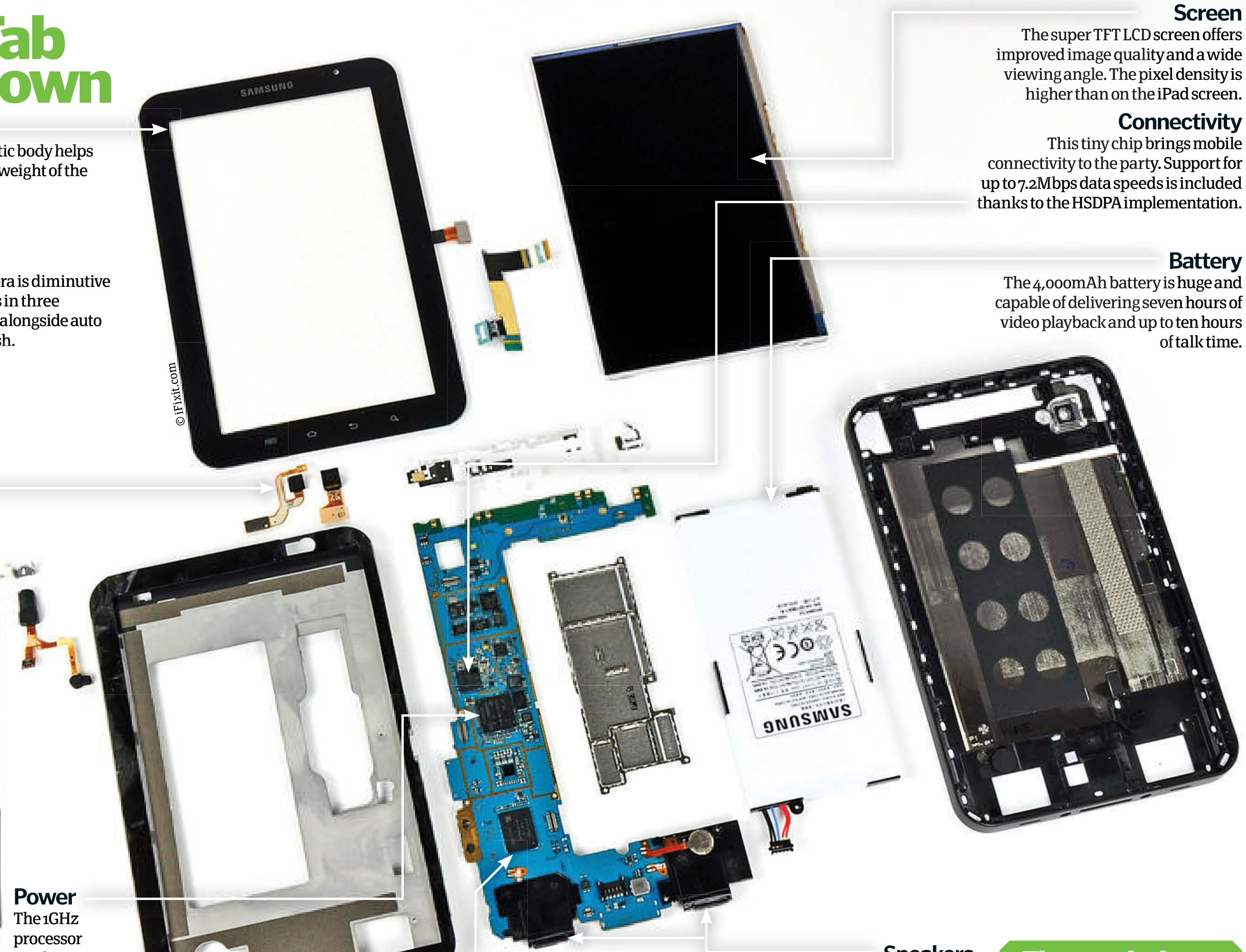
BIGGEST
© Apple

3. Apple iPad

With a 9.6-inch screen the iPad lets you enjoy web browsing and many other tasks more than the others, but at the cost of true portability.

DID YOU KNOW? *The Tab offers full Adobe Flash compatibility, which does not natively work on the iPad*

The Tab teardown



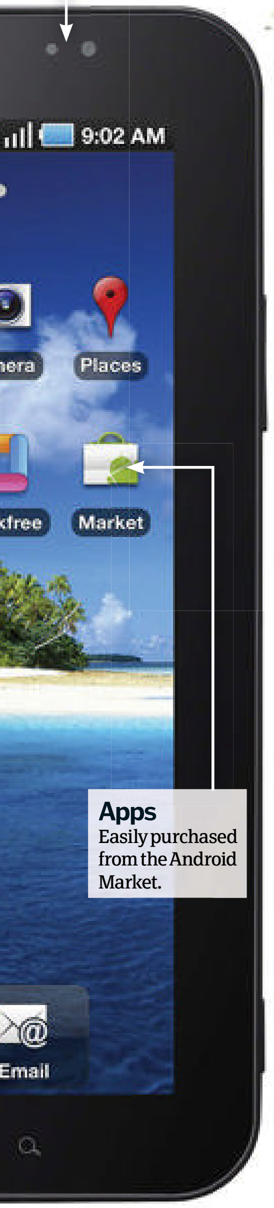
Plastic
The lightweight plastic body helps to reduce the overall weight of the Tab greatly.

Rear camera
The rear-facing camera is diminutive in size, but still packs in three megapixels of power alongside auto focus and an LED flash.

Screen
The super TFT LCD screen offers improved image quality and a wide viewing angle. The pixel density is higher than on the iPad screen.

Connectivity
This tiny chip brings mobile connectivity to the party. Support for up to 7.2Mbps data speeds is included thanks to the HSDPA implementation.

Battery
The 4,000mAh battery is huge and capable of delivering seven hours of video playback and up to ten hours of talk time.



Apps
Easily purchased from the Android Market.

Power
The 1GHz processor produces excellent speed and is also designed to be as power efficient as possible.

Memory
Up to 32GB of flash memory is built in to the Tab, which complements the microSD expansion slot.

Speakers
The Tab has two built-in loudspeakers, which help deliver a superior stereo sound. The positioning also makes it less likely to cover them with your hands.

Tab vs Pad

Apple's iPad and Samsung's Galaxy Tab are at opposite ends of the scale in terms of size, weight and operating system. They have similar goals, but the Tab's Android OS is open and iOS on the iPad is very much closed. Along with the materials and builds, the differences are numerous

Samsung Galaxy Tab

☑ Small and light; much more portable than the iPad

☑ Two cameras for snaps and more personal communication

☑ 3G connectivity built in as standard

☒ The plastic cover feels a little cheap for the price

☒ Expensive and only one model available

☒ Android OS is not completely refined for the tablet form yet

Apple iPad

☑ Stunning build quality and a beautifully designed screen

☑ Many magazine and news publications already support the format

☑ The optional keyboard turns it into a mini-laptop

☒ Expensive for the 3G-enabled version and locked to a contract

☒ Little choice for customising the software interface

☒ The iPad is large and heavy and not the most portable

The statistics...

Galaxy Tab

Dimensions: 120 x 190 x 12mm (4.7 x 7.4 x 0.4in)

Weight: 380kg

Display: 1024 x 600 pixels

OS: Android 2.2 (Froyo)

Processor: 1GHz ARM Cortex A8

Memory: 16 / 32GB

Battery: 4,000mAh

Camera: 3MP (rear) + 1.3MP (front)

Pricing: £517 ($807)

Learn more

For more info and images of the exposed Galaxy Tab, visit the gadget surgeons at **ifixit.com** who kindly contributed photos and findings for this article.

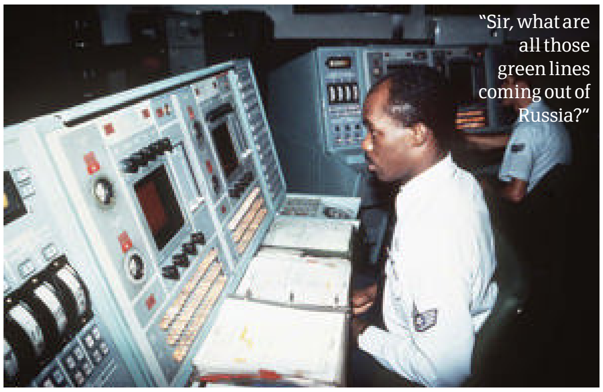
ifixit

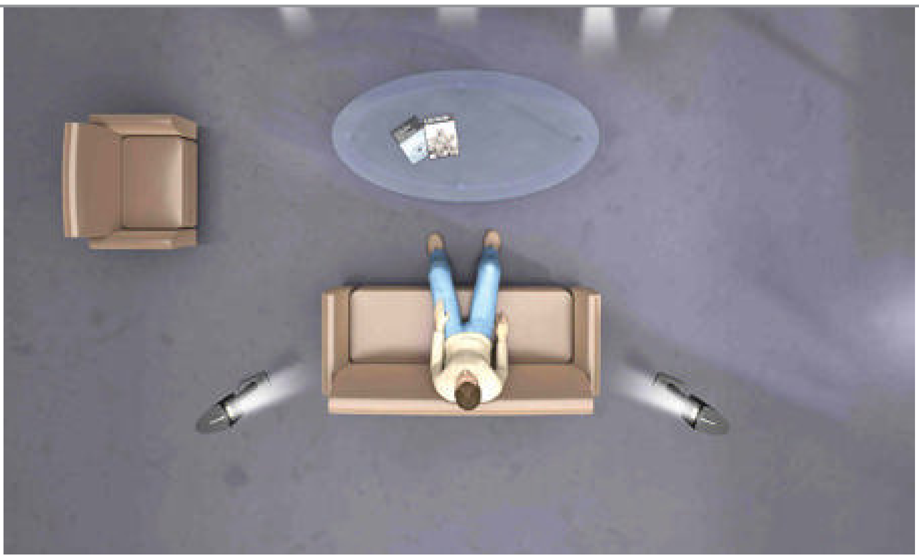
How does radar work?

Discover why sound inspired radiowave observation?

Radar uses a radiowave-based version of echo location to find moving and stationery objects. When you make a noise in a space that echoes, the sound is bounced back to you – you hear it again a moment or so later. If the sound is moving, somebody standing still and listening to you will hear the sound go up and down as it moves past them. This is called the Doppler effect.

We can't go around shouting at aeroplanes in order to find them, no matter how frustrating Terminal 5 can be, so instead radiowaves are used. They produce exactly the same phenomenon as sound. For example, an aircraft is fitted with a radar transmitter. When another transmitter sends a burst of radiowaves in its direction, they're bounced back. The speed with which they bounce back, and the wavelength of the waves, determine where the aircraft is and the rate at which it's moving relative to the transmitter.


"Sir, what are all those green lines coming out of Russia?"



Understanding digital sound

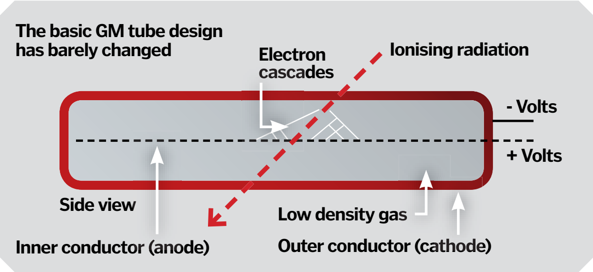
We've come a long way from the gramophone, but what exactly is digital sound?

Record collections may still be en vogue, but both vinyl and cassette mediums represent an archaic analogue technology that has long since been superseded by CDs and MP3. Imagine the pits and grooves in a record or the magnetically charged surface of tape that store the information as a variable wave: in contrast, digital sound is stored as a series of distinct peaks and troughs, rather like the battlements of a castle. Translating from analogue to digital is called 'encoding' and in terms data storage, it saves an enormous amount of space.

This is the basis of Dolby's digital audio technologies and the encoding process allows companies to tease apart digital sound into separate channels for a surround sound experience. Take 5.1 surround sound, for example. This consists of a left and right channel communicating movement, a focused centre channel for dialogue, a pair of surround channels, and a resonant low-frequency bass.

How Geiger counters detect radioactivity

We explain how the Geiger counter measures radiaton and reveal what causes that clicking noise we associate with the device


The basic GM tube design has barely changed

The Geiger counter was invented by Hans Geiger and Ernest Rutherford in 1908 to detect alpha particles – one of the four main types of radioactivity (the others being beta, gamma and x-rays). It was later modified by Geiger and his student Walther Müller to detect the others and again in 1947 by Sidney Liebson into the halogen counter – which is the technology still widely used today.

A Geiger counter typically consists of four parts: a power supply, a visual and audio readout and the crucial Geiger-Müller tube that measures the radiation. The GM tube is filled with a low pressure inert gas such as neon, helium, argon and, most commonly today, halogen. It is usually coated with metal or graphite to create the cathode, while the anode wire, charged with around 1,000 volts, passes through the centre. GM counters work by pointing at a suspected source of radiation, which releases pairs of ions and electrons in the gas that are attracted to the negative cathode or positive iode. It is this cascade of charged particles that creates the electrical current measured by the audio readout, usually an oscilloscope or LCD display, in milliroentgens (or microsieverts) per hour. It is the readout or speaker that creates the 'click' for each particle registered. The more rapid the clicks, the more intense the radioactivity.

Historically, Geiger counters were used to prevent human exposure to harmful levels of ionising radiation, which can cause anything from minor skin burns to fatal cancers and genetic damage. At the height of the Cold War they were routinely supplied to civil authorities and even hospitals in preparation for nuclear war, however these days their use is far more diverse, ranging from astronomy, medicine and engineering to military environments.

DVD burning explained

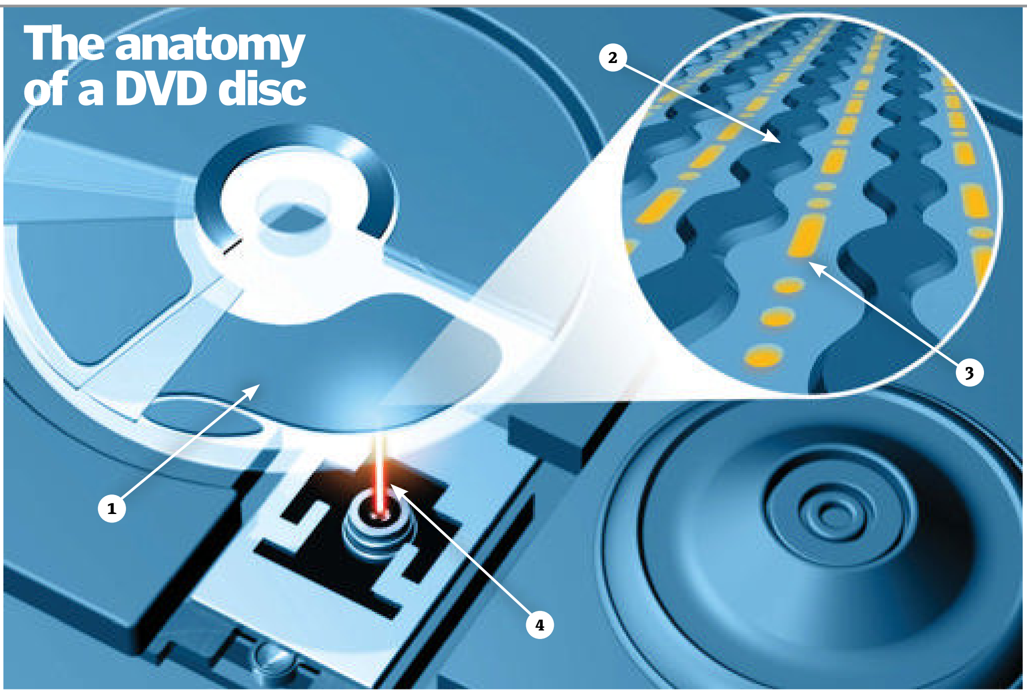
Just what happens after you click the burn button?

So you've got a DVD burner and some software like Nero or Toast and you want to transfer some video you've shot to DVD. Ever wondered how your PC and that software accomplish this task? Well here's the answer…

Hitting the Burn button will start the burning life cycle, which is essentially a four-step process. The first step is the process of converting the existing video file into a format that can be read from the DVD. This is known as transcoding and will take a proportionate amount of time depending on the file size. The next part in the process is building, which is the construction of the disc. This is where menus, links and navigation are put together to make sure they work on the disc.

The next stage is the big one where the information is written to the disc. This involves the physical process of transferring the data from the hard drive and placing it onto the disc. How long this part of the operation takes depends on a number of factors, including the DVD writer's burnspeed capabilities. Then there's the lead out, which marks the end of the burning process. This ensures a player or program does not get confused and tries to read any further into the disc.

Burning your own video content to a recordable DVD disc doesn't hold any legal issues, the content is yours. However, commercial DVD movies do have copyright issues. It is illegal to make even a single copy of a DVD and most DVD-burning software does not allow the copying of protected material. There is commercially available software that will remove copy protection, allowing users to make backups of their favourite movies. AnyDVD (www.slysoft.com) is a program that removes copy protection on a DVD movie as soon as it's inserted into the drive. This then allows users to back up the movie using a DVD-burning tool. Theoretically, individuals could face up to two years in jail, an unlimited fine and possible civil action from the copyright holders.



The anatomy of a DVD disc

1. Recording layer
A dual-layer disc has two recording layers. Layer 0's metallic coating is altered to become translucent, allowing the laser to pass through it when focused on Layer 1.

2. Wobbled groove
This is embedded in the plastic surface and provides the recorder with the timing information needed to place data accurately on the disc.

3. Pits
Pits or bumps, depending on which side you look from, are where the laser heats up a tiny pinpoint of dye. This changes the dye's physical build, burning on data.

4. Laser
DVD recorders use a red laser to read and write DVDs. The reading laser is not as strong as the writing laser because it does not need to heat up the recording layer.

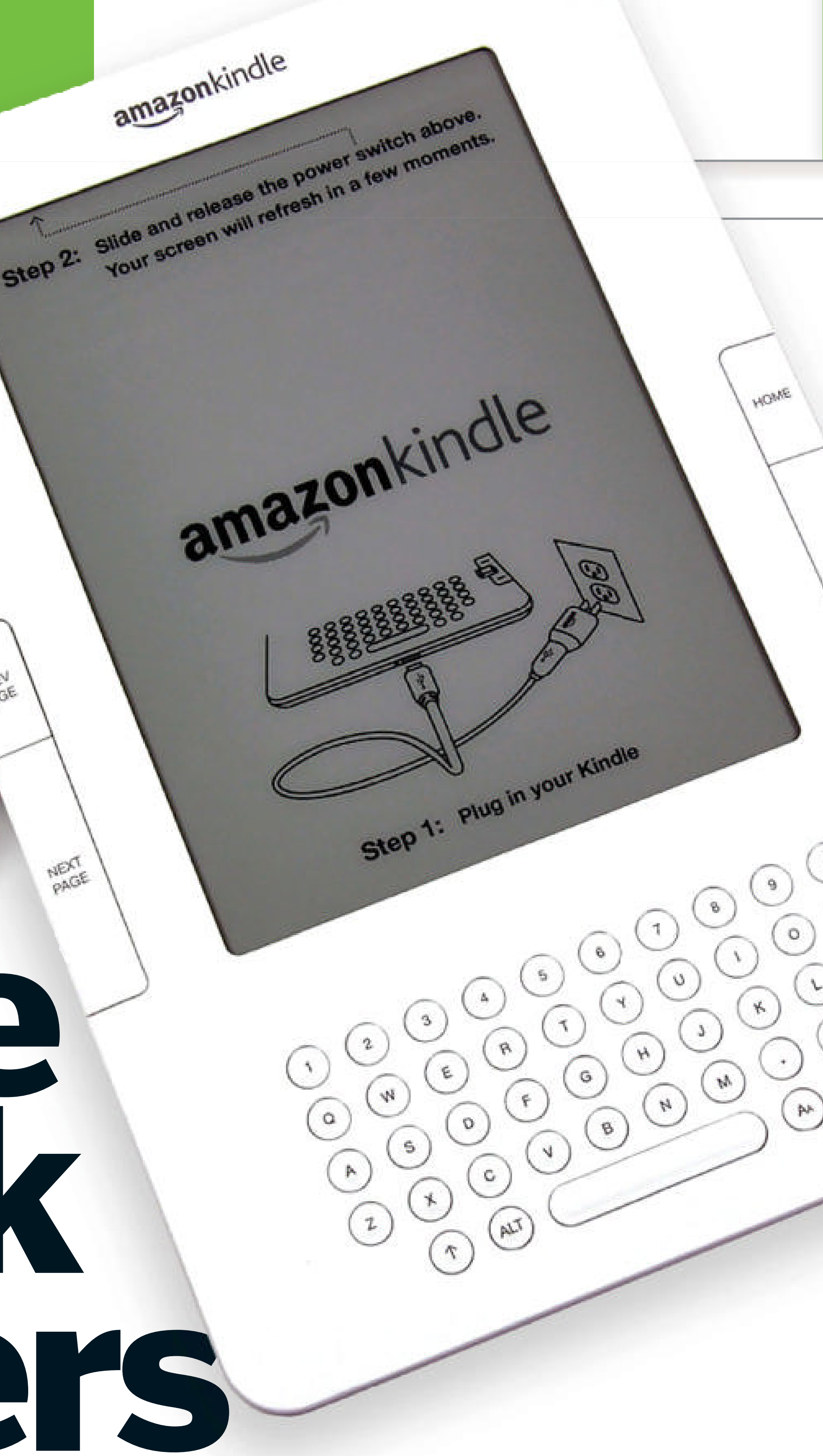
How night-vision goggles work

From air-sea rescue to counter surveillance, night vision goggles have literally changed the way we see

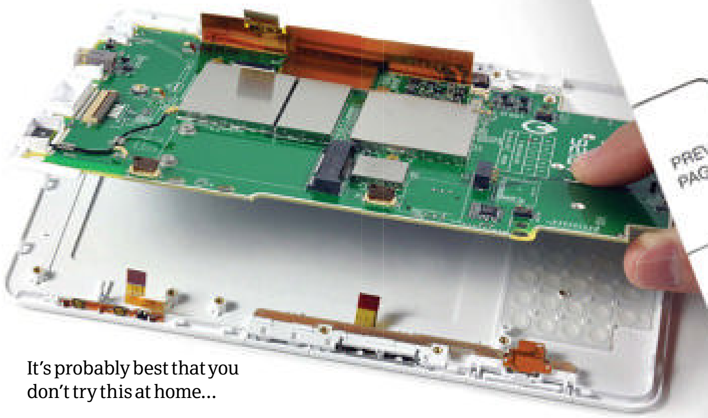
Night vision typically utilises two types of technology: thermal imaging (infrared) and image intensification or light enhancement, of which the latter is the most portable and therefore suitable for use in night vision goggles. Light Enhancement devices take the photons present in ambient light (typically moon or starlight) from the front lens, pushing them through a photocathode tube that converts them into electrons, a microchannel plate containing millions of photoelectric channels that multiplies them before bouncing them against a phosphor screen to convert back into the distinctive green-tinged image seen through the eyepiece.

Night vision was first developed for tanks by both sides in WWII before being made portable for sniper scopes in Vietnam and finally for goggles in the Fifties. Now used by military, police and rescue operations worldwide, devices are classified as Generations 0-3, with consumer (Gen 1) devices starting from as little as £200 to far more expensive and sophisticated Gen 3 devices for military and counter-surveillance purposes.

I can see you…
No longer will total darkness prove an obstacle


amazonkindle
Step 2: Slide and release the power switch above.
Your screen will refresh in a few moments.
amazonkindle
Step 1: Plug in your Kindle
PREV PAGE
NEXT PAGE
HOME

> "eBook applications are now available for the iPhone and Android systems"



It's probably best that you don't try this at home…

Inside eBook readers

A whole library in the palm of your hand

An eBook reader is a device that can read eBooks, digital versions of popular books, enabling you to carry a number of novels with you on one device. However, not all eBook readers were created equal and there are many different types.

Many convergence products, such as smartphones and PDAs, are capable of being used as eBook readers, but these don't benefit from the electronic ink used in dedicated devices. Electronic ink is being developed by two key players: E Ink Corporation and Xerox. While both are being developed to work in different ways, they have some similarities, like the ink being made up of microcapsules filled with ink or an oily substance. White particles carry a positive charge and the black ones carry a negative charge. When integrated into a screen fitted with microelectronics, the screen will be made of tiny cells, which could apply a negative or positive charge to the microcapsules making them visible or invisible on the screen, creating text. A lot of the better-known eBook readers use E Ink Corporation's Vizplex Imaging Film, including the Barnes & Noble nook, the Cybook Opus, the BeBook and the Amazon Kindle.

Another important point of note is that different eBook readers will read different electronic formats. Not all will

5 TOP FACTS eBOOK READERS

Storage solution

1 The Amazon Kindle can store thousands of books at any one time, making it a perfect holiday companion, especially as it weighs less than 280g (10oz).

Here in 60 seconds

2 The wireless Kindle uses Whispernet to enable you to search for books and download them on the go, with a delivery time of less than 60 seconds.

No charge

3 The great thing about the Kindle's wireless internet access is that it is free – Amazon pays for the connectivity as part of the service.

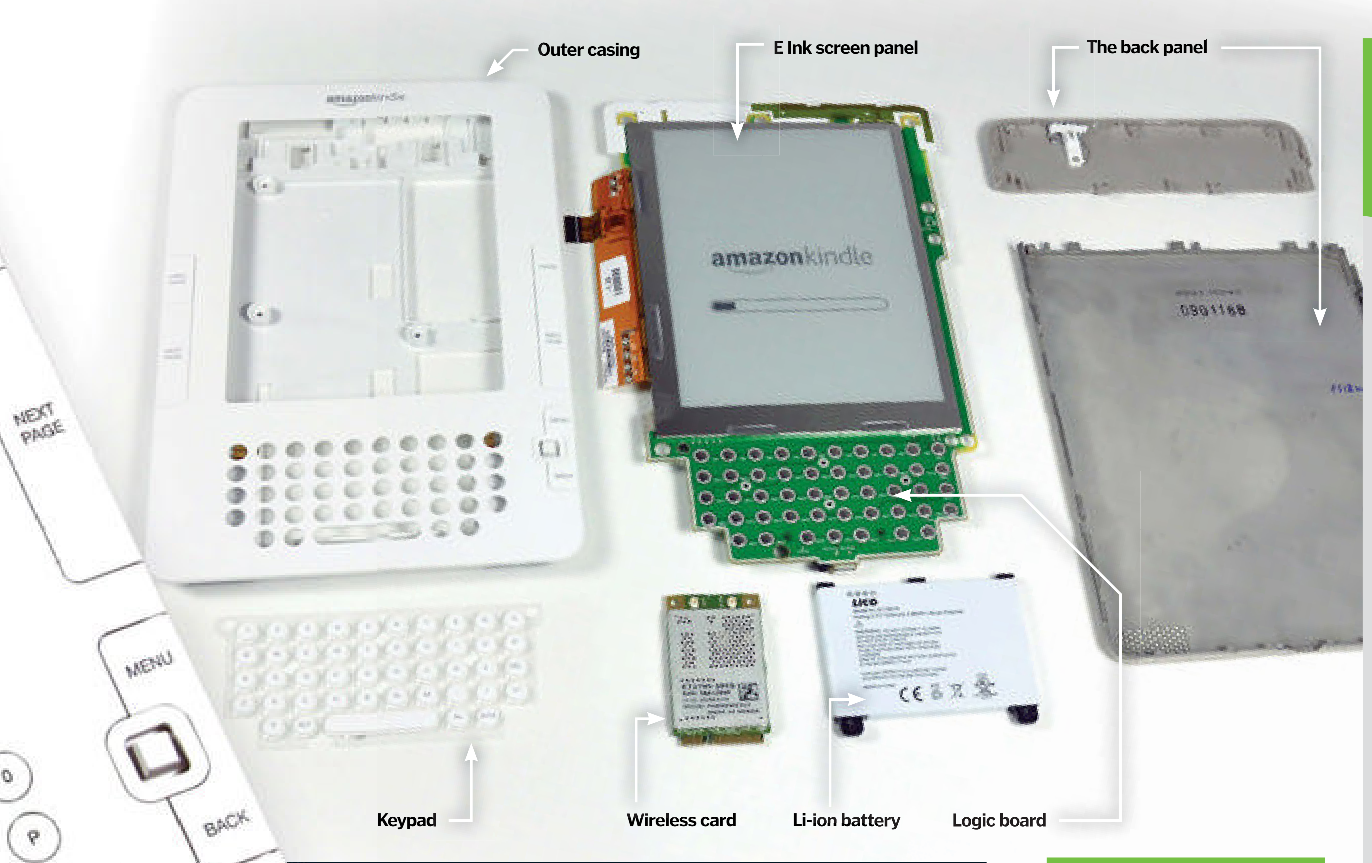
Power it up

4 A single charge will last for four days with wireless on and two weeks with it turned off, but it is easy to recharge using the power cable or via USB.

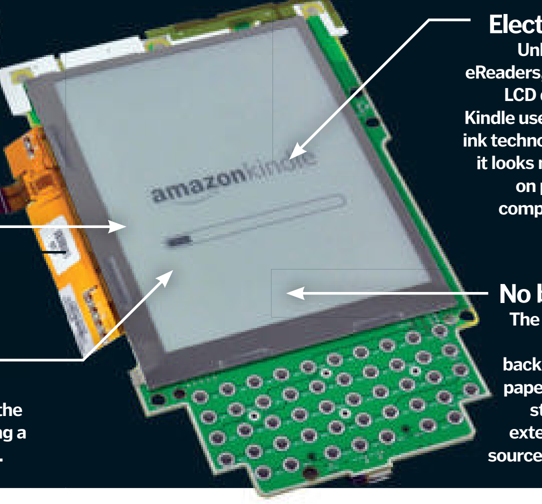
Subscription services

5 In the United States, where this remarkable device was launched, it's possible to subscribe to newspaper and magazines electronically so you're always updated.

DID YOU KNOW? *Many eBooks have a text-to-speech feature that can read text out loud to give your eyes a break*



The Kindle's screen



Electronic ink
Unlike previous eReaders, which used LCD displays, the Kindle uses electronic ink technology so that it looks more like ink on paper than a computer screen.

Monochrome
The Kindle may only works as a monochrome device right now, but a colour Kindle is on the way.

No backlight
The screen does not have a backlight, so, like paper books, you still rely on an external lighting source for viewing.

Energy saving
The device uses very little energy, only drawing from the battery when it is generating a page view for the first time.

recognise the PDF format natively, often relying on specially designed formats, meaning that users have to stick to a particular type of eBook format to suit their device. There is a massive list of formats, from the Kindle format for Amazon's Kindle (.azw) to TomeRaider (.tr2, .tr3) for certain mobile devices, including the Windows Pocket PC devices.

The current generation of Amazon Kindles incorporate internet access via 3G and Wi-Fi, so content can be downloaded using Amazon's Whispernet service. Kindle applications are also available for the Apple iPhone and Windows systems, making this device a real competitor in the eReader market. ⚙

Learn more

For more information about the Amazon Kindle head to **http://www.ifixit.com** where you can get an in-depth look at the components of the device, the components of the device, and how they all work together.

BUYING AN eBOOK VIA 3G
[STEP BY STEP]

1 Browsing
To get a new book, click Menu, then Shop in Kindle Store to start browsing papers, magazines, books and blogs.

2 The categories
You can search for a title just like the usual Amazon store, by entering a keyword or simply browsing categories.

3 Large library
There are over 350,000 books so it's easy to find exactly what you're looking for, plus personalised recommendations.

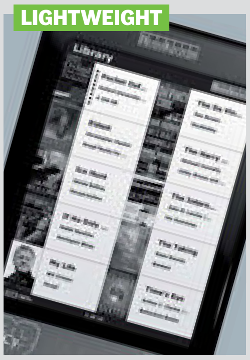
4 Download sample
You can download a sample of a book for free before actually buying, but when you are ready a press of the five-way controller purchases and downloads the book.

5 Purchasing
Purchased books are backed-up in the Kindle library by Amazon.com for re-downloading.

6 Whispers
Whispernet delivers books, magazines and newspapers wirelessly using 3G connectively. International roaming is currently active in 100 countries.

Head to Head eBOOK READERS

LIGHTWEIGHT



1. Cybook Opus
Screen size: 5in
Storage space: 1GB
Resolution: 600x800
Touch screen: No
Battery life: 8,000 pages
Weight: 150g

TOUCH SCREEN

2. Sony PRS-600
Screen size: 6in
Storage space: 512MB
Resolution: 600x800
Touch screen: Yes
Battery life: 7,500 pages
Weight: 286g

MOST STORAGE

3. COOL-ER
Screen size: 6in
Storage space: 1GB
Resolution: 600x800
Touch screen: No
Battery life: 8,000 pages
Weight: 178g

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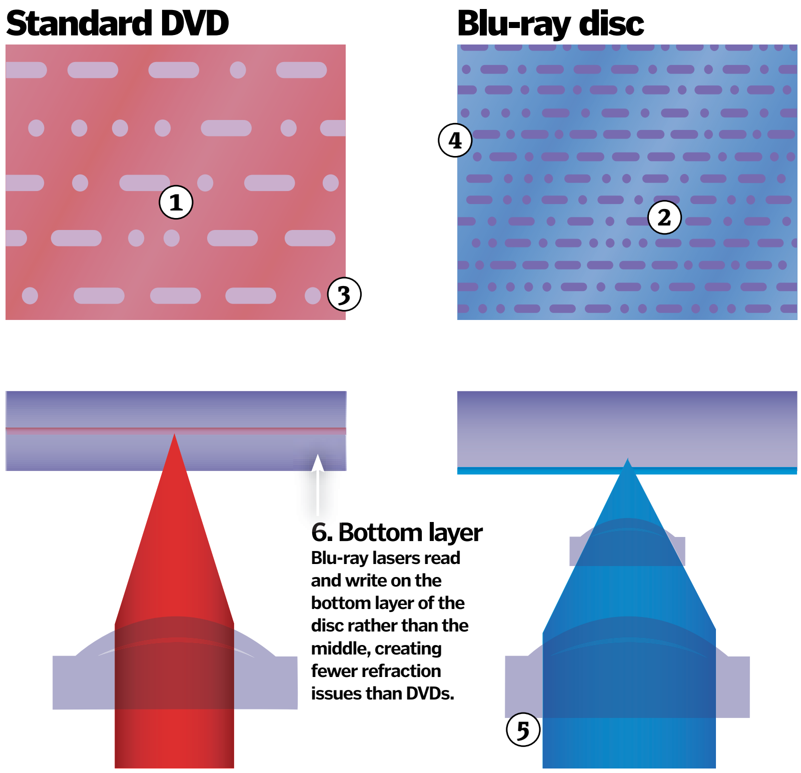


6. Bottom layer
Blu-ray lasers read and write on the bottom layer of the disc rather than the middle, creating fewer refraction issues than DVDs.

1. Red
Red lasers with a wavelength of 650nm can produces a 'pit' with a minimum size of 0.4 microns.

2. Blue
Blue lasers with a 405nm wavelength can produce slightly smaller pits at just 0.15 microns.

3. Pitch
The distance between tracks is called the pitch. A normal DVD has a track pitch of 0.74 microns.

4. Tighter
However, Blu-ray discs have a much tighter track pitch, coming in at only 0.32 microns.

5. Precision
The numerical aperture (NA) of the lens rates its precision and resolution. Blue lasers have a higher NA.

Blu-ray discs

Blu-ray technology leaves DVDs in the dust

Watching a Blu-ray movie on a very large, very expensive HDTV is a transformative experience. It's the kind of experience that makes you want to convert your garage or basement, install stadium seating, 7.1 surround sound speakers, an industrial popcorn maker and then start charging the neighbours admission. But what is it that makes Blu-ray discs so much sharper and richer than regular DVDs?

It all comes down to data. A regular DVD can hold 4.7GB of data, while a single-layer Blu-ray disc can hold 25GB. What that means is that Blu-ray discs can handle very large video files, exactly the kind of barely compressed video and audio that looks and sounds insanely good on the latest home theatre rigs.

Blu-ray gets its name from the blue-violet laser used to read and write data on Blu-ray discs. Regular DVDs and CDs use a red laser, which has a larger wavelength. The shortened wavelength of the blue laser offers greater precision, allowing manufacturers to write data in tightly packed rows. This is why Blu-ray discs can squeeze in six times as much information per layer than a regular DVD.

All of that data translates into more pixels on the screen. A regular DVD image maxes out at 480p, which is shorthand for 852 horizontal pixels by 480 vertical pixels. If you play a regular 480p DVD on a 1080p HDTV (1920x1080 pixels), the image will have to be 'upconverted' to the larger screen size. The result is like blowing up a low-megapixel digital picture.

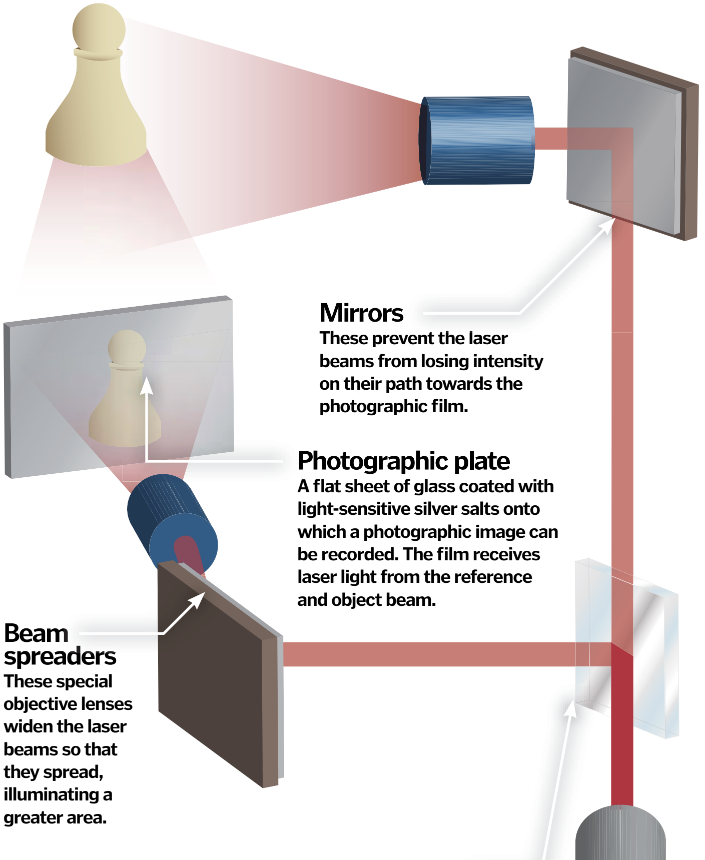
A Blu-ray disc, however, can hold a full 1080p video file that syncs perfectly with the 1080p native resolution of your brand-new TV. The result is a huge, sharp image that rivals – if not tramples – the big screen experience.

Holograms

How are these artificial three-dimensional images produced?

A hologram is a 2D image that seems to have real three-dimensional depth. Though Hungarian physicist Dennis Gabor invented holography in 1947, he could not put his theory into action until the invention of the laser in 1960. You see, to create a hologram you require the monochromatic light – that being light of a single wavelength – produced by a laser. The process relates to how the light is reflected onto a sheet of photographic film. A single laser beam is split into two – an object beam and a reference beam – by an appropriately named beam splitter, which allows part of the beam to pass through it and deflects the rest at a 90° angle towards the photographic film.

As the object beam heads towards the object, it passes through a beam spreader that diffuses the light, illuminating more of the object. En route to the photographic film, the reference beam also passes through a beam spreader to widen the beam and light up the holographic image. The two beams meet at the same point on the photographic film, creating an interference pattern that's preserved in the layers of silver in the film and gives contours to the hologram.



Mirrors
These prevent the laser beams from losing intensity on their path towards the photographic film.

Photographic plate
A flat sheet of glass coated with light-sensitive silver salts onto which a photographic image can be recorded. The film receives laser light from the reference and object beam.

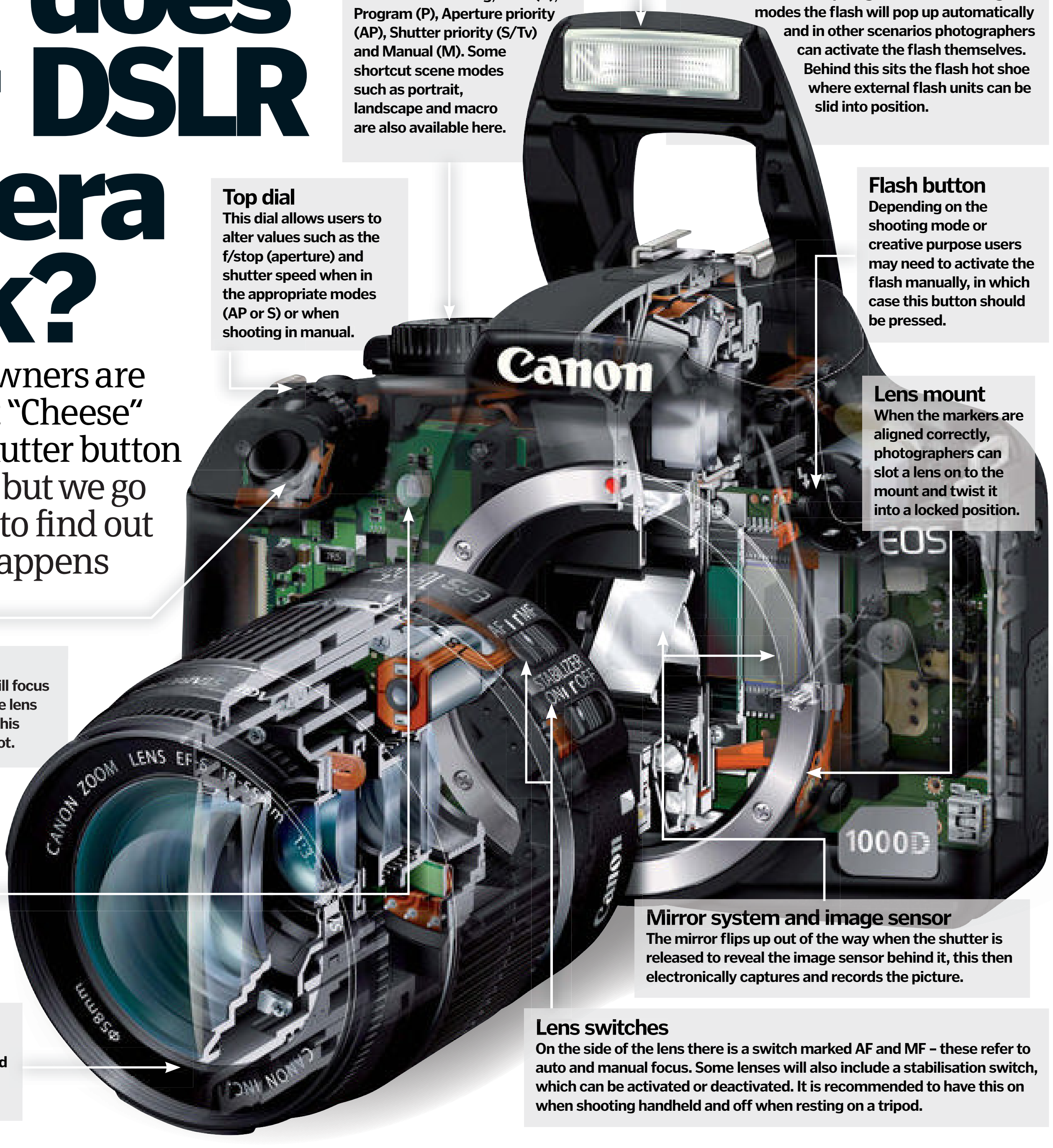
Beam spreaders
These special objective lenses widen the laser beams so that they spread, illuminating a greater area.

Beam splitter
A half-silvered mirror, consisting of a thin plate of glass coated in a tiny amount of aluminium. Approximately half the light passes through and the rest is deflected at a 45° angle.

DID YOU KNOW? *The first digital camera to go on sale was a Kodak DSC-100 in 1991 hosting a petite 1.3 megapixel sensor*

How does your DSLR camera work?

Many camera owners are content to shout "Cheese" and push the shutter button to get an image, but we go under the hood to find out exactly how it happens



Main dial
All the shooting modes are positioned on this dial including; Auto (A), Program (P), Aperture priority (AP), Shutter priority (S/Tv) and Manual (M). Some shortcut scene modes such as portrait, landscape and macro are also available here.

Built-in flash
Most DSLRs will accommodate a 'built-in' or 'pop up' flash tucked into the top ledge. In some shooting modes the flash will pop up automatically and in other scenarios photographers can activate the flash themselves. Behind this sits the flash hot shoe where external flash units can be slid into position.

Top dial
This dial allows users to alter values such as the f/stop (aperture) and shutter speed when in the appropriate modes (AP or S) or when shooting in manual.

Flash button
Depending on the shooting mode or creative purpose users may need to activate the flash manually, in which case this button should be pressed.

Lens mount
When the markers are aligned correctly, photographers can slot a lens on to the mount and twist it into a locked position.

Shutter button
Depressing this button half way will focus the lens on the scene in front of the lens when set to Auto Focus. Pressing this button completely will take the shot.

Focus Assist beam
When shooting in low light levels a light will emit from this area, illuminating the subject to help the autofocus find it's focus point. In many cameras this also doubles up as the self timer indicator, where it will flash during the countdown.

Lens
The larger ring on the lens body operates the lens's focal length and the front, the smaller ring controls the focus when in manual.

Mirror system and image sensor
The mirror flips up out of the way when the shutter is released to reveal the image sensor behind it, this then electronically captures and records the picture.

Lens switches
On the side of the lens there is a switch marked AF and MF – these refer to auto and manual focus. Some lenses will also include a stabilisation switch, which can be activated or deactivated. It is recommended to have this on when shooting handheld and off when resting on a tripod.

The dawn of the digital format has revolutionised the imaging industry and in turn the way we work our cameras. Furthermore the internal DNA of the camera body has been entirely restructured to make way for the new electrical system; or has it?

In fact film and digital cameras operate in a similar manner. Varying the size of the lens's diaphragm (aperture) in tandem with the amount of time the shutter is open, focusing light onto the image detection material, the only difference being that this is now received in an electrical rather than chemical form.

A DSLR (digital single-lens reflex) camera employs a mechanical mirror system that directs the light travelling through the attached lens upwards at a 90-degree angle allowing the photographer to compose the shot through the viewfinder. As the shutter button is pressed the exposure takes place: the mirror swings out of the way and the shutter opens allowing the lens to project the light on to the image sensor. In low light scenarios the shutter will need to stay open for a longer period of time for the image to be recorded, this is why photographers support their cameras with tripods as the smallest degree of camera shake will disturb the quality.

The sensor is formed of millions of pixels laid out in thousands of rows and columns: the more pixels or dots of light, the higher the megapixel count and in theory the higher the resolution. The light travels through a colour filter above the individual sensors and is converted from light waves into an analogue signal which is then processed through a digital convertor. Next the conversion is fine tuned through a series of filters that adjust aspects such as white balance and colour. The resulting image can be made into a JPEG by compressing the file size and discarding unnecessary pixels. The final image is shown on the LCD screen.

Electronic hearing

'Bionic ears' restore hearing to the profoundly deaf

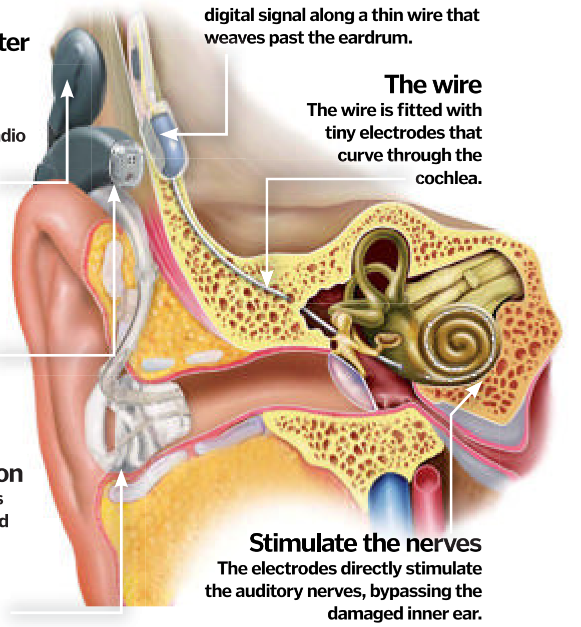
The ear is a miraculous piece of biological circuitry. The outer ear captures sound waves and corrals them to the eardrum, which vibrates subtly with each whisper or bang. The vibrations are captured by three tiny piston-like bones and transmitted to the inner ear, or cochlea, a snail-shaped spiral filled with fluid and hair cells. Fluid waves in the cochlea stimulate the hair cells, which convert the liquid motion into electrical impulses that are sent to the brain via auditory nerves. And that, put simply, is what we call sound.

Unfortunately, even the best evolutionary wiring can short circuit. In cases of nerve deafness – profound hearing loss that strikes both young and old – the hair cells are damaged or missing and sound waves never make it past the cochlea.

In the late-Eighties, medical researchers developed the cochlear implant, a radical new technology for 'curing' nerve deafness. The device uses an external microphone and an internal electrode array to transmit digital sound directly to the auditory nerves.

With the cochlear implant, a small disc-shaped receiver is surgically implanted into the bony plate behind and above the ear and a delicate string of electrodes is fed past the eardrum into the spiral of the cochlea. Sound waves captured by a small microphone worn above the ear are sent through a tiny digital processor that converts the sound to electronic impulses. The impulses travel through the skin to the implanted receiver, which then sends the signals down the electrode array to the auditory nerves.

While cochlear implants cannot restore normal hearing, they are sensitive enough to replicate both loud and quiet sounds and, with the assistance of speech pathologists and therapists, many formerly deaf patients can now learn to communicate without sign language or lip reading.



Transmitter
An external transmitter sends the signals via radio waves to the transplanted receiver.

Mic
Sound is captured by external microphone.

Conversion
Sound waves are converted into digital signals by a sound processor.

Internal receiver
The internal receiver sends the digital signal along a thin wire that weaves past the eardrum.

The wire
The wire is fitted with tiny electrodes that curve through the cochlea.

Stimulate the nerves
The electrodes directly stimulate the auditory nerves, bypassing the damaged inner ear.

How Bluetooth works

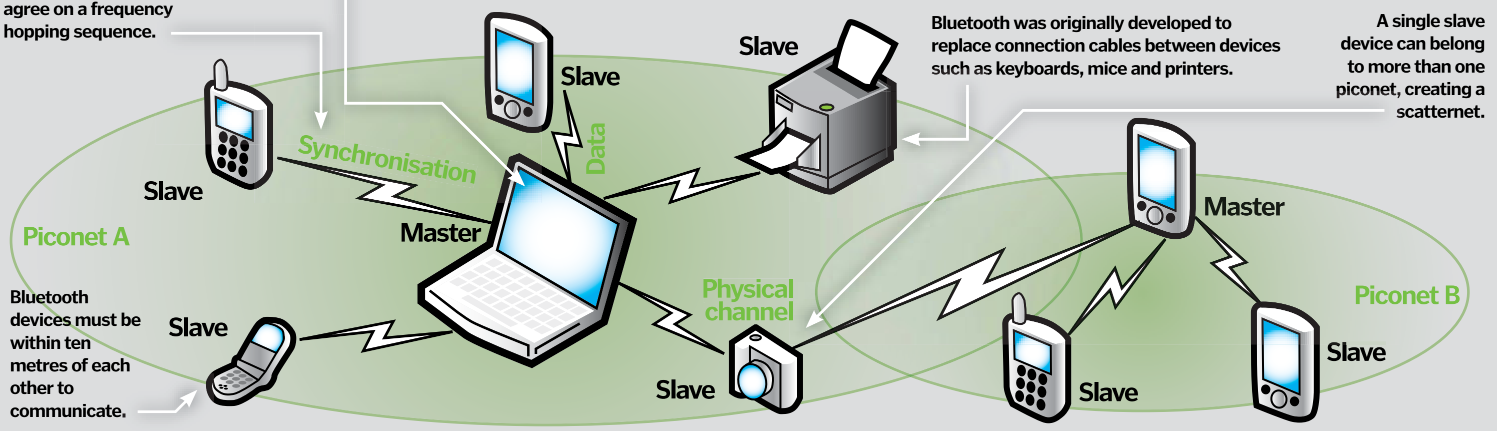
Cableless communication that we use on a day-to-day basis

Any Bluetooth-enabled device can be a master or slave, depending on which device initiates the connection.

During the synchronisation process, the two devices agree on a frequency hopping sequence.

Bluetooth was originally developed to replace connection cables between devices such as keyboards, mice and printers.

A single slave device can belong to more than one piconet, creating a scatternet.



Bluetooth devices must be within ten metres of each other to communicate.

Bluetooth has turned our Inspector Gadget fantasies into reality. Mobile phones that stream music to the car stereo, open the garage door and call friends hands-free. Fashionable bracelets that vibrate gently to signal an incoming call, stethoscopes that transmit heart and lung readings directly to a laptop and restaurant tables that double as touch-screen menus.

But exactly how does Bluetooth get all of these gadgets to speak the same language? It's all about radio signals. Every Bluetooth-enabled device is equipped with a tiny radio transceiver mounted on a chip. The transceiver has a range of ten metres (33 feet), within which it can communicate with any other Bluetooth-enabled device.

Bluetooth devices are bundled with software that helps two or more gadgets connect and share data. In all Bluetooth relationships there is a 'master' and a 'slave'. The master device initiates communication by sending out a page. If the slave accepts the connection, it synchronises with the master and the two begin an intricate dance called frequency hopping.

Frequency hopping is a method for sending and receiving packets of data with limited interference and tight security. Bluetooth radios can choose from 79 RF channels. Every time a device sends or receives a packet, it switches to a different channel. The master choreographs the dance and the slave keeps in step.

When two or more Bluetooth devices connect, it's called a piconet or a personal area network (PAN). A single device can connect with up to seven other devices within the same piconet, and that same device can join several overlapping piconets at the same time, making the options almost limitless, and what will be developed next really is anyone's guess.

0.2
Bulls Copse Road
Bulls Copse Road
93
Arrival
8:50
Speed
40
GARMIN nüvi

Map view
Locations and nearby points of interest are displayed on the map

Text-to-speech
Text-to-speech will read website information to you while you drive

Instant updates
Live Traffic gives you instant updates on the state of the roads

Meet Garmin nüvi 1690, the satnav that gives you live updates via cellular connection

Connected GPS

Satnav devices have got the A-to-B route planning down to a fine art – simply load up your destination and the combination of 3D mapping and voice guidance will get you to where you want to go. So where does satnav go next? The answer is connectivity. The new Garmin nüvi 1690 comes with a built-in SIM card that creates a permanent data connection to the internet, enabling the device's nuLink software to download relevant information about your journey as you drive, from traffic to weather to real-time fuel prices at nearby petrol stations.

It's easy too, and perfectly integrated into the all-round functioning of the device, and turns the satnav system into a kind of 'location aware' internet tablet. In practical terms this means you can use the Google Local Search feature to search for, say, Indian restaurants, and the resulting list of results will show said establishments listed in order of their proximity to you. And because it uses exactly the same technology that powers Google on a desktop computer you get all the added interactive benefits of that service as well – things like restaurants and hotels will also often be accompanied by user ratings and reviews, so you're not simply finding your nearest restaurant, you're finding the best one. This Google search feature is one of the highlights of nuLink, complementing the traditional points of interest database in the device with more relevant and up-to-date information.

The other key benefit of the service is the live traffic information that it provides. This gives you the chance to see any potential jams on your route ahead, and you can set the system to automatically reroute you to avoid them, or you can take your chances and deal with any possible delays on a case by case basis. Regular build-ups of traffic, for example, might have cleared by the time you reach them, while serious road works will most likely not have.

By having its always-on data connection, the Garmin nüvi 1690 is able to deliver other information straight to you as you drive. The fuel price service removes the 'cat and mouse' approach to filling up on a long journey, nuLink shows you the prices at all your upcoming petrol stations so you can easily compare. Another useful money-saving feature is Garmin's ecoRoute application. Enter a few details about your specific make of car and the way you drive and ecoRoute will plot your journey in the most fuel-efficient way – it's unique to you, will show exactly how much money you will save, and as an added bonus helps you cut down on your carbon footprint as well.

These features show the direction that tomorrow's satnav systems are heading. No more are they mere digital atlases, but rather fully interactive and personalised devices that deliver highly contextualised information. Whether you want to know what the weather is like at your destination, whether your flight is on time, or where you should meet your friends when you arrive it is all possible, and much more besides.

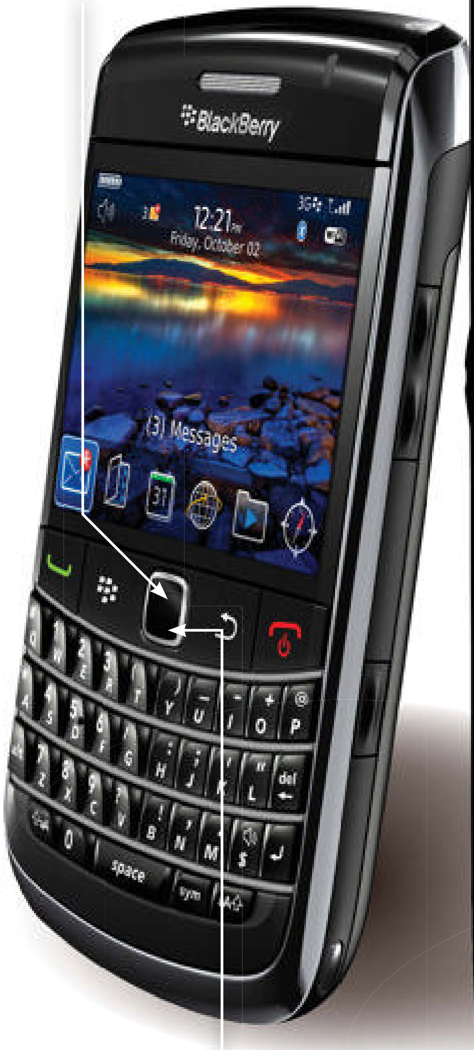
The Statistics

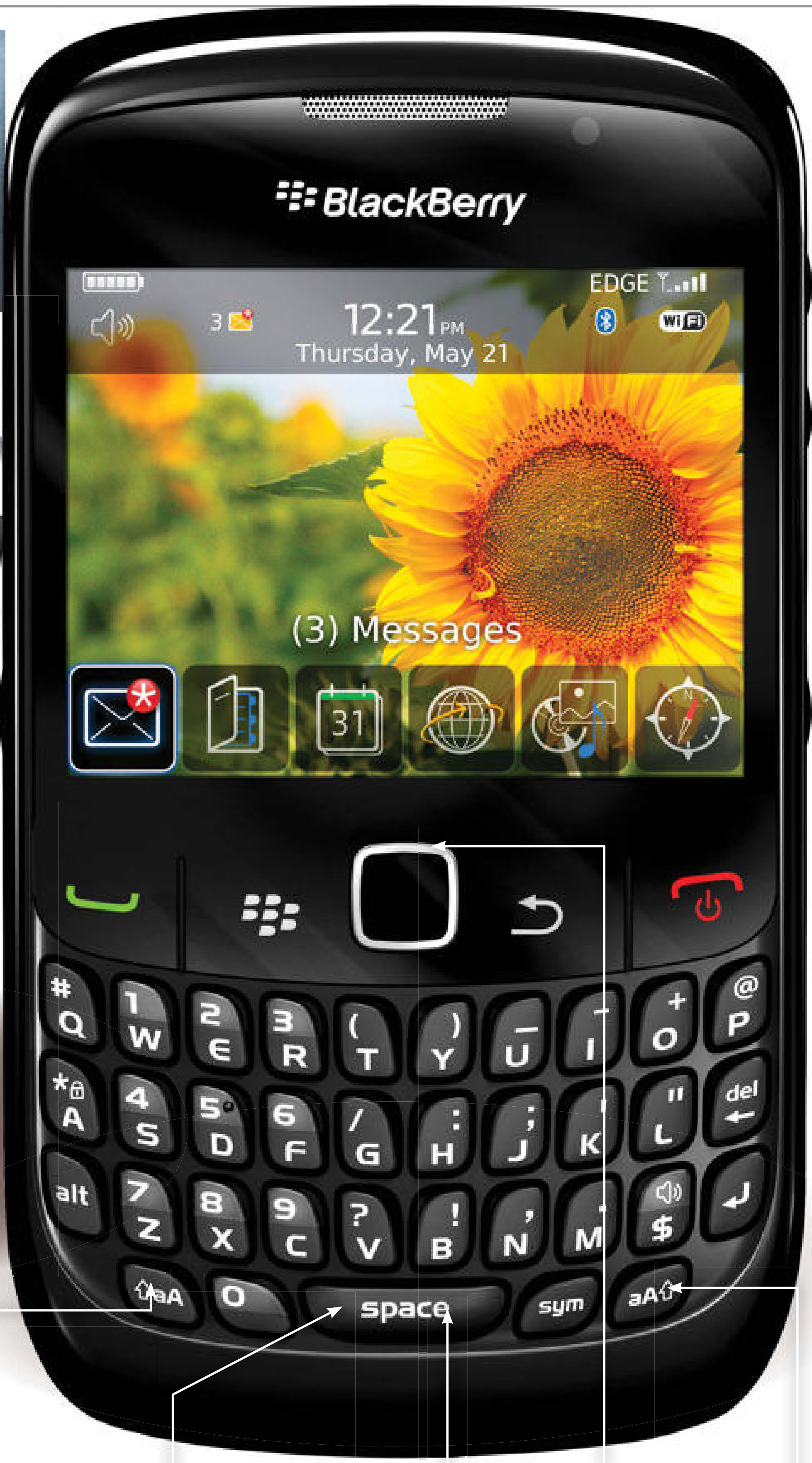
Garmin nüvi 1690

Today
Current Location
66° / 55°
Precip.: 70%
Humidity 63%
62°, Feels Like: 62°
Wind: SW at 16 mph
Forecast
GARMIN nüvi

Operating system: Proprietary
Software: City Navigator Europe NT 2010
Map coverage: Western & Eastern Europe
Installation: Pre-installed on internal flash memory (amount N/A)
Additional storage: microSD card
Dimensions: 79 x 125 x 19mm
Weight: 174.7g
Display: 4.3"
Additional features: Bluetooth, one year nuLink Live services

Mobile email has revolutionised communication…





Highlight text
Hold Shift and move trackball

Copy text
Press Alt and click trackball

NUM Lock
Alt+Left shift

Auto full stop
Press the spacebar twice

Insert @ symbol
Press spacebar (in email field)

Paste text
Hold Shift and click trackball

CAPS Lock
Alt+Right shift

BlackBerry shortcuts

How the BlackBerry keyboard makes typing easier

5 TOP FACTS BlackBerry

An app for everything

1 The BlackBerry App World has around 10,000 programs that can be installed, enabling the BlackBerry to perform almost any function you can imagine.

50 million BlackBerrys

2 As one of the biggest phone platforms in the world the BlackBerry has sold over 50 million units to businesses and ordinary consumers alike.

The range

3 There are several models of BlackBerry handset, including Bold, Storm, Pearl, Curve and Touch. The Touch now has the full touch-screen functionality in the style of Apple's iPhone.

SureType keyboards

4 The Pearl range of BlackBerrys include a SureType keyboard which combines a Qwerty layout with the more traditional numeric keypad.

Short cuts

5 The BlackBerry keyboard is packed full of shortcuts. For example, hitting the spacebar in an email address will automatically insert the @ symbol.

DID YOU KNOW? *The first BlackBerry was launched back in 1999, not as a phone, but as a pager*

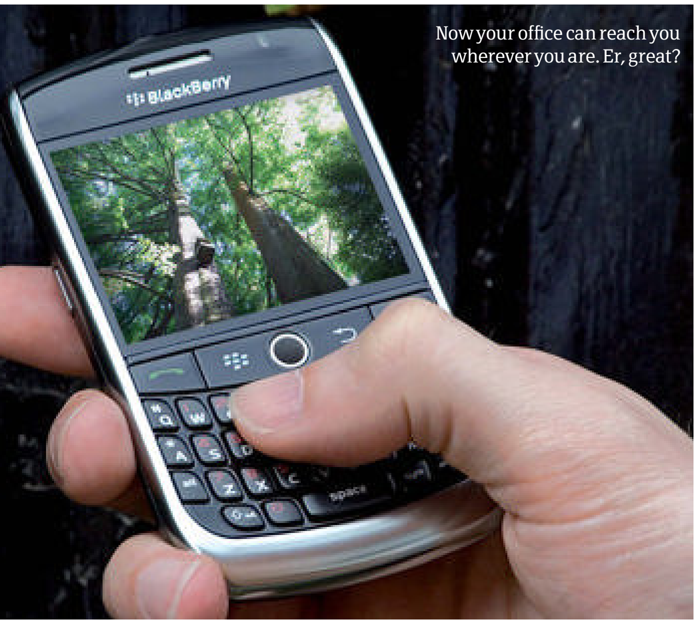
Inside a BlackBerry

They are the must-have gadget for the discerning business user, but what is it that makes the BlackBerry such a popular phone?

Originally launched back in the Nineties as a simple paging device, the BlackBerry has grown into one of the biggest and most recognisable mobile phone brands, the pride and joy of business users the world over. The secret of its success was simple: the BlackBerry completely rewrote the rulebook on how we use email. No longer did you need to be tied to a desk, and a desktop computer, to check your inbox, you could do it on the go. Even more importantly, through the BlackBerry's revolutionary 'push email' concept you could read your messages instantly.

Push email works by routing your traditional inbox via the BlackBerry servers, accessed by signing up to either the BlackBerry Enterprise Service (BES) for businesses or the Internet Service (BIS) for individual users. As soon as a new mail drops into your inbox, BIS (or BES) instantly 'pushes' it to the BlackBerry handheld associated with the account. There's no clicking of a Send/Receive button in the mail client, no waiting for 15 minutes for the email app to poll your inbox. With a BlackBerry email is instant – more akin to the immediacy of text messaging than the email we are more used to on a PC. It's this instant delivery that sold the BlackBerry concept to businesses, while in the last couple of years the simplicity of the service combined with more attractively designed hardware has increased its appeal to ordinary consumers as well. Now, a fifth of all the smartphone users in the world carry a BlackBerry.

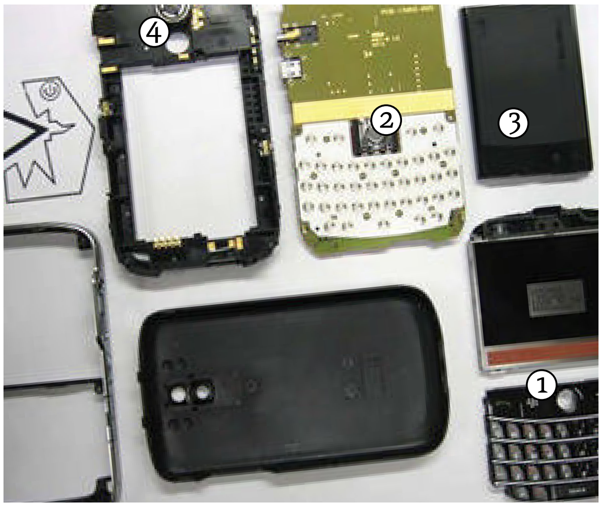
Of course, a pocket-sized email device would be useless without the BlackBerry's second point of genius, the thumb keyboard. The trademark Qwerty keyboard that sits below the handset's screen seemingly defies the laws of engineering. It's tiny, cramped and should be impossible to use with any comfort, yet with subtle design touches and intelligent short cuts it is somehow possible to type even lengthy emails at fast speeds. Other phone manufacturers have tried to replicate this, but the BlackBerry is still going strong. ⚙



Now your office can reach you wherever you are. Er, great?

How it works

What's under the skin of the BlackBerry…



1. The keyboard

The 35-key thumbboard comes in the normal Qwerty layout similar to any desktop keyboard. Despite its compact size it enables the user to type quickly and at some length.

2. Trackball

The trackball offers the quickest way of navigating. You can control how fast you scroll through webpages or documents simply by changing the speed at which you move the trackball.

3. Large capacity battery

The 1500mAh battery is as large as in any mainstream device, and delivers a couple of days' use on a single charge, unlike many devices that need a daily charge.

4. Two megapixel camera

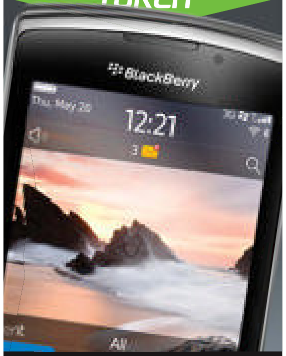
Although not a major focus of the BlackBerry range, the camera is good for snapshots, and the always-on internet connection on the phone makes it easy to share them.

Screen: 3.5 inches
Memory: 32GB
Camera: 5MP autofocus
Battery: 7 hours 3G talk time

iPHONE 4

VS

BLACKBERRY TORCH



Screen: 3.2in
Memory: 32GB
Camera: 5MP
Battery: 5.8 hours talk time

Learn more

For more information about BlackBerry and other mobile devices, head over to **www.smartphonedaily.co.uk** where you can catch up on all the latest smartphone news and reviews.

SmartphoneDaily

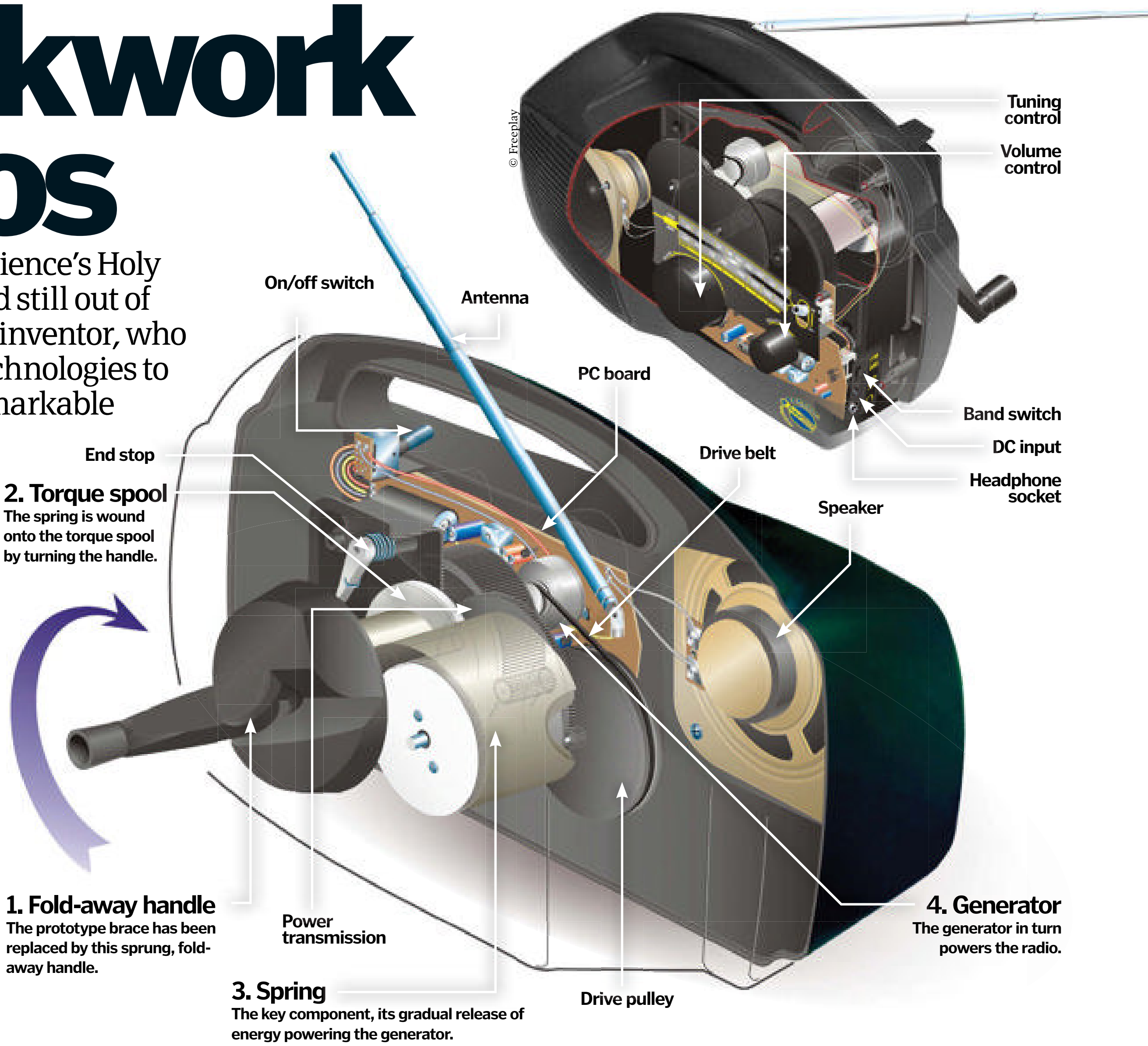
© Images from ifixit.com

Clockwork radios

Free energy, one of science's Holy Grails for decades and still out of reach. Except for one inventor, who combined two old technologies to create something remarkable

Trevor Baylis invented the clockwork radio in 1993 to help get information about AIDS to outlying regions of Africa that had no electricity. The device gets around this by having the user provide the electricity, turning a hand brace. The brace, a tool originally intended to help drill holes in wood, provided enough electricity to power an attached motor and radio for short periods.

His real breakthrough came, however, when he added a clockwork mechanism, the energy imparted by turning the brace being stored and then unwound by the clockwork spring at a set rate, meaning the radio could be powered for far longer. The prototype ran for 14 minutes on a two minute wind while later models would run for up to 50 minutes.



1. Fold-away handle
The prototype brace has been replaced by this sprung, fold-away handle.

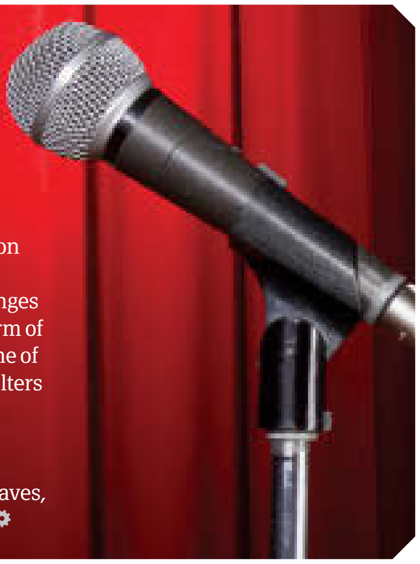
2. Torque spool
The spring is wound onto the torque spool by turning the handle.

3. Spring
The key component, its gradual release of energy powering the generator.

4. Generator
The generator in turn powers the radio.

How does a microphone work?

Understanding the technology that lets you belt out your favourite track when you're singing karaoke…



All microphones utilise a diaphragm, designed to vibrate when hit by sound waves. These vibrations travel into the microphone causing the contained components to move. The energy is converted into an electrical current which becomes an audio signal. There are five varieties of microphone, each utilising a different method for the conversion.

Carbon mics use carbon dust, so that when sound hits the diaphragm the dust compresses altering its resistance, by running a current through the carbon the changing resistance alters the amount of current that flows. Dynamic mics employ electromagnets that move when the diaphragm vibrates, therefore creating a current. Ribbon varieties utilise a thin piece of ribbon suspended by a magnetic field. Sound waves flex the ribbon which changes the current flowing through it. Condenser mics are a form of a capacitor, storing and sharing an electrical charge. One of the internal plates moves in response to sound which alters the ability to hold the charge; these changes create a measurable signal. Crystal microphones feature a diaphragm with an attached crystal. Certain crystals change their electrical properties when hit by sound waves, these changes are amplified into an electrical charge.

E-Lites
60
NO TAR
NO TOBACCO

© E-lites

© E-lites

The electronic cigarette's atomiser

Electronic cigarettes

How do these zero tar, zero tobacco cigarettes help smokers quit?

Electronic cigarettes, such as the E-Lites brand pictured here, work by turning liquid nicotine into vapour by heating it up in an atomising chamber, allowing it to then be inhaled by the user through a plastic inhaler. The cigarette consists of five main components: an indicator light on the tip of the cigarette, which lights up when nicotine is inhaled; a battery encased in the cigarette's body to power the atomiser; the atomiser itself (a small piece of equipment used to convert liquid to vapour); and a microchip regulator and indicator to control the amount of nicotine atomised and inhaled in one go, and the plastic inhaler.

Out of the box, in order for users to smoke the electronic cigarette, they must first charge its battery component. The battery on the electronic cigarette is charged up through a USB connection hub – a process that takes approximately 30 minutes for a full charge. Once the battery is charged – this is necessary to power the atomiser – users can then connect the atomiser and nicotine cartridge. Each nicotine cartridge provides 12 cigarettes' worth of nicotine, with each cigarette constituting 12 inhalations through the inhaler.

These electronic cigarettes are tobacco and tar free, which is beneficial to their users as they contain zero carcinogens and no harmful additive chemicals. Furthermore, they are smoke free, with only a sweet-smelling vapour exhaled by their users. As with regular cigarettes, the electronic variant is not for sale to anyone below 18 years of age.

Polygraphs

How can they tell if you're lying?

A polygraph works by measuring multiple physical characteristics of a person while they're asked questions to which – so the theory goes – they'll answer either truthfully or deceptively, with deceptive answers detectable by fluctuations of the aforementioned signs. The polygraph doesn't detect if someone is telling a lie, however, it only tells you if they are exhibiting 'deceptive behaviour'.

The three main physiological areas the polygraph monitors are respiratory rate, which is measured by affixing two pneumographs (rubber tubes filled with air) to the test's subject's chest and abdomen; blood pressure/heart rate, which is measured by the traditional manner of fastening a cuff around the subject's upper arm; and galvanic skin resistance, which detects how sweaty you are, measured by attaching fingerplates called galvanometers to the subject's fingertips.

Traditionally the information garnered from these instruments was translated and displayed on an analogue polygraph system, which consisted of a scrolling sheet of paper and a series of pen-filled mechanical arms, each attached to a set of bellows that in turn were attached to the individual instruments. So, for example, when a subject's chest muscles expanded due to heavy or fast breathing, the bellows would inflate and deflate, controlling the movement of the arm and the marks it left on the sheet of paper. Over the past 20 years, however, digital polygraph machines have become the machine of choice, utilising computer software to decode the instruments' results.

Polygraphs don't actually detect lies, they monitor the physical attributes associated with lying

© Science Photo Library

3D cameras

Understanding parallax, stereoscopic effects and the third dimension

FUJIFILM
3D
SP1
SP2
MENU /OK
DISP/ BACK
3D
2D↔3D

© Fujifilm

5 TOP FACTS
3D CAMERA HISTORY

1838
1 Charles Wheatstone and Fox Talbot worked together on stereo photography, which enabled pairs of identical images to be combined and viewed in 3D with glasses.

1900
2 The introduction of the small portable cameras, imaging only in 2D but easy to use, rapidly reduced the popularity of stereo photography, sending 3D imagery into obscurity.

1950s
3 3D-mania struck again when colour camera film and a new stereo camera allowed comic books, movies and pictures to all be produced in the exciting third dimension.

1960
4 Interest in 3D waned once more with the commercial success of compact cameras like the colour Polaroid, with 3D cameras remaining less portable and needing glasses.

2010
5 The release of the Fujifilm FinePix camera brings compact 3D cameras into the modern age, allowing images to be viewed in 3D without the need for special glasses.

DID YOU KNOW? *Lenticular displays use prisms or lenses to make the left and right images visible only to the left or right eye*

With 3D becoming big business in the cinemas, it was only a matter of time until the consumer market demanded the ability to capture the third dimension, too. A number of camera manufacturers have come up with ways to create 3D images including software and lens solutions, but only one camera is currently available to the consumer market that can produce a 'true' 3D image.

The Fujifilm FinePix Real 3D W3 can produce a true 3D image because of its unique dual lens and sensor design. The two lenses are set approximately the same distance apart as a pair of human eyes – mimicking the sense of depth that we get when we view things with our own eyes. The twin lenses capture two images simultaneously – similar to how your right and left eye would 'see' two different images – and the 3D processor converts these two images into a single 3D image file. By layering the two 2D images on top of one another, the camera is able to create one single stereoscopic 3D image with depth, or the allusion of it.

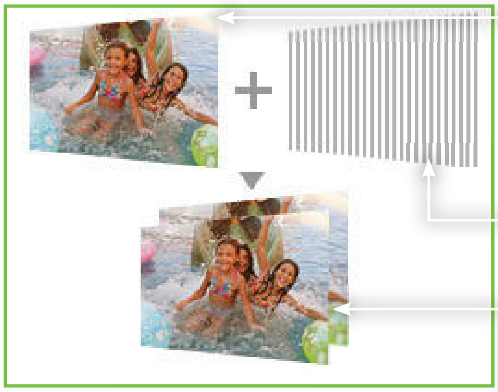
The 3D effect is created by taking two images from two lenses, creating a parallax effect. Parallax occurs from viewing an object along two lines of sight – try holding a pencil up in front of your eyes, then close one eye and then the other to see the pencil shift slightly each time.

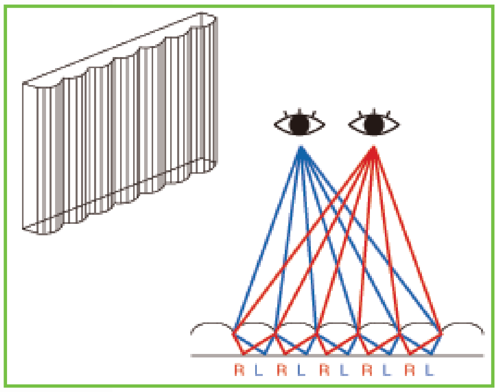
To achieve the best 3D effect, some subjects work better than others. For instance, the camera will only work in landscape orientation. Images taken with the camera in a vertical orientation are more difficult as your eyes cannot adjust to the parallax (as it is at a 90 degree angle). Images with some depth will work better – for instance those photos with subjects at two metres, five metres and eight metres – while macro shots, night time images and compositions where the subject is near the edge of the frame will not be as effective.

However, it is not the creation of 3D images that is problematic, but more the displaying of them. But with 3D-ready TVs making an appearance on the market, 3D solutions from other camera manufacturers are sure to follow suit.

© Fujifilm

The science bit…





1. In the eyes
For a 3D camera to produce a 'true' 3D image it needs two lenses. Human eyes are generally around 64mm apart, but the lenses on the W3 are 20 per cent further apart to add extra depth to shots, says Fujifilm.

2. Replicating sight
To replicate human sight, a 3D camera produces an image that can be viewed through a series of magnified multiple lenticules aligned on a lenticular sheet from left and right angles.

3. Left versus right
Both eyes see a different image, and the parallax between each eye creates the 3D look in the image.

4. Understanding parallax
To understand how each eye sees a different parallax image, simply hold a pen in front of your eyes and close each one in turn, you will see the pen move as you switch between eyes.

5. Choosing the shot
Images work best when something is happening in the fore-, mid- and background of a shot, each stage seeming to float on its own 3D layer.

Does 3D really work?

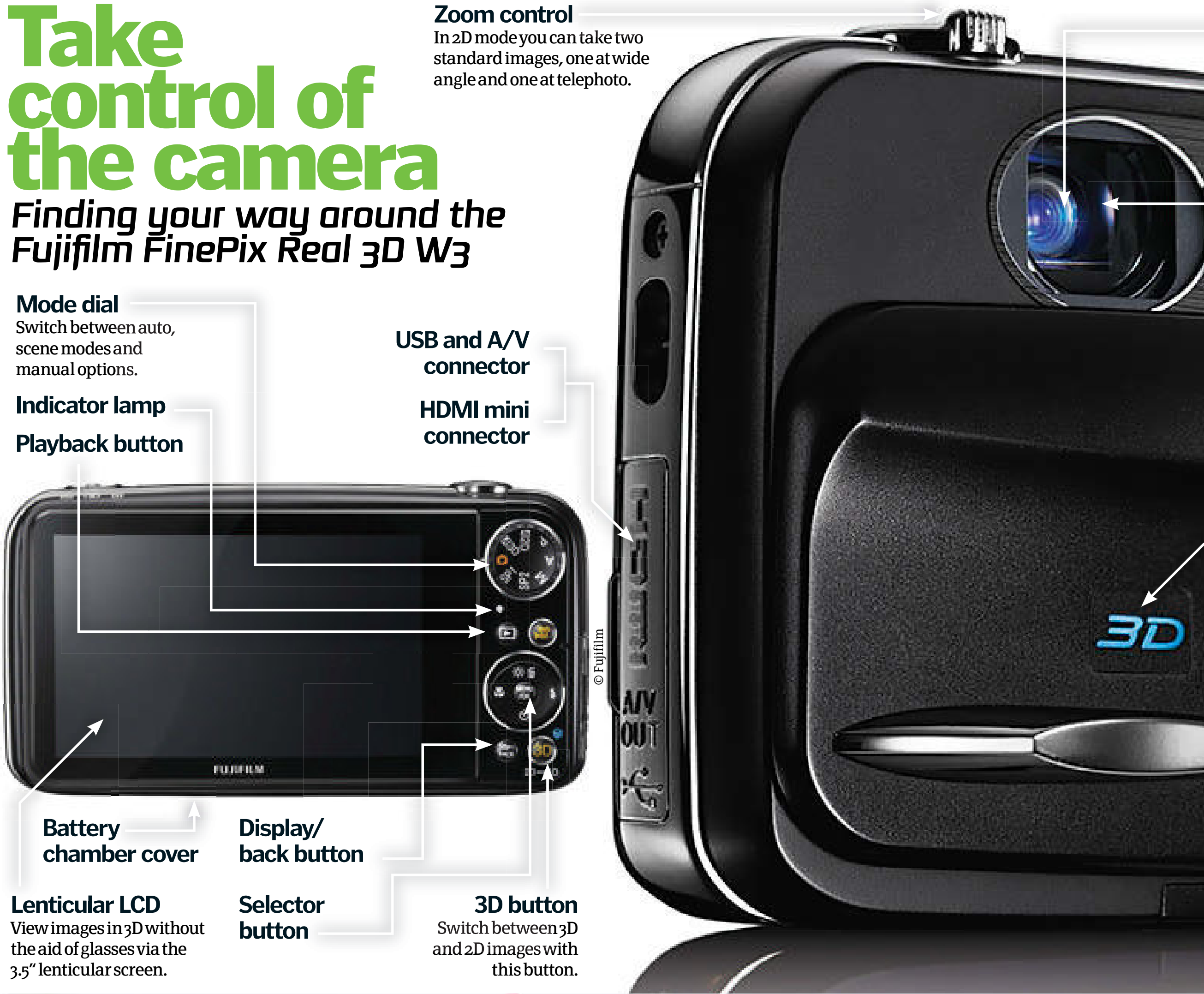
Is there any way to properly view your images?

3D images taken with any 3D consumer camera can be viewed on a 3D-ready TV, via special 3D prints or on the back of the camera (in the case of the Fujifilm camera). In order to create the illusion of depth and a better 3D image, composition is important and setting up a shot with elements in the foreground, midground and background achieves the 3D effect best. Each stage of the image seems to float on its own layer and projects out towards the viewer. Images are best viewed straight on, while holding the camera at an angle disturbs the 3D look.

While the technology works exceptionally well, presently 3D consumer cameras are hindered by the way you view the images after capture. 3D prints are expensive and time-consuming to produce, 3D TVs are still in their infancy and viewing images on the back of your camera has its drawbacks too.

Take control of the camera

Finding your way around the Fujifilm FinePix Real 3D W3



Zoom control
In 2D mode you can take two standard images, one at wide angle and one at telephoto.

Mode dial
Switch between auto, scene modes and manual options.

Indicator lamp

Playback button

USB and A/V connector

HDMI mini connector

Battery chamber cover

Display/ back button

Lenticular LCD
View images in 3D without the aid of glasses via the 3.5" lenticular screen.

Selector button

3D button
Switch between 3D and 2D images with this button.

© Fujifilm

Images work best with bright colours, layers and distance. Here the landscape in the background, the child in the mid section and the petals at the fore work particularly well for 3D images

Head to Head 3D CAMERAS

SOFTWARE SYSTEM

© Sony

1. Sony NEX
This software-based system combines multiple images from one lens to create a '3D' image that can be viewed on a 3D TV with special glasses later.

LENS SYSTEM

© Panasonic

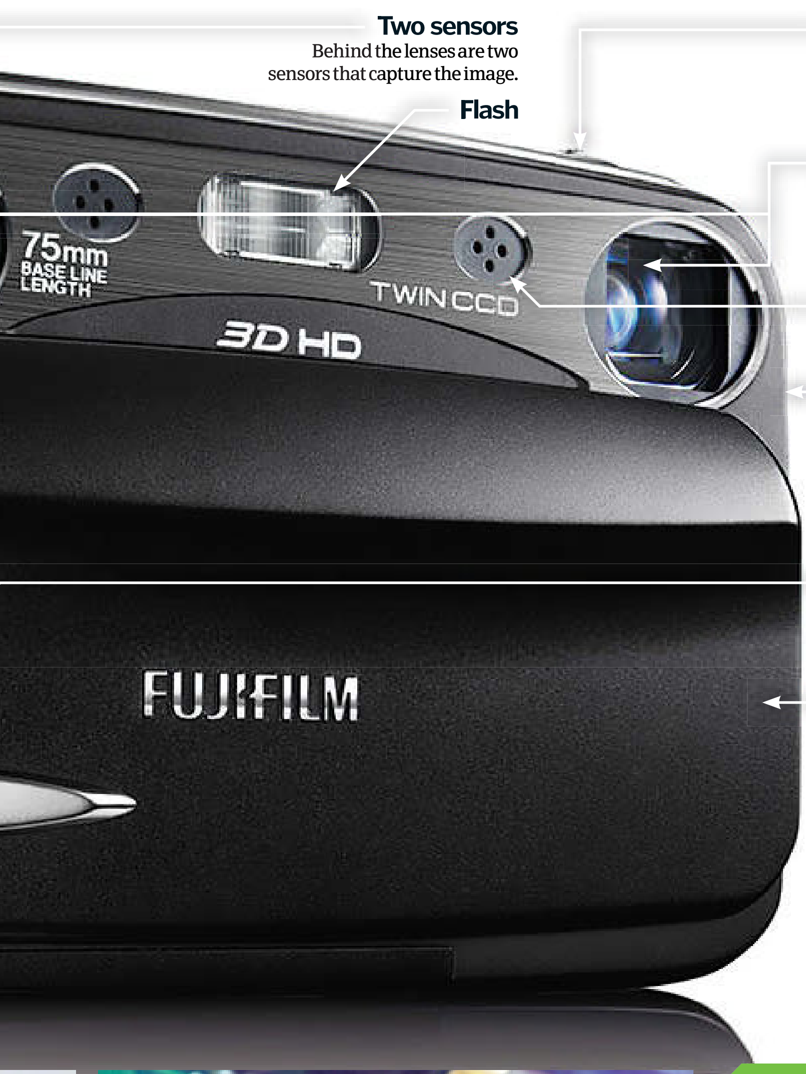
2. HDC-SDT750
This lens-based system boasts dual lenses, but one sensor, taking two images of the same subject and then combining them to achieve a 3D effect.

THE ORIGINAL

© Fujifilm

3. Fujifilm FinePix 3D W1
The first camera to deliver true 'binocular parallax' 3D photos rather than software interpolated images, giving you the best results.

DID YOU KNOW? *Studies show one in ten people in the UK can't process images from the left and right eyes individually*



Two sensors
Behind the lenses are two sensors that capture the image.

Flash

Parallax control
This slider fine-tunes the amount of parallax in your 3D images.

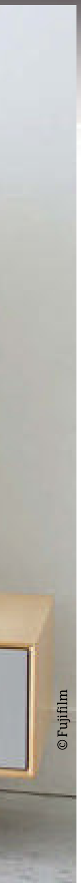
Dual lenses
The twin lenses enable the camera to take two shots in one.

Microphone

Real Photo Processor 3D HD
The dual 2D images are combined by the processor to create a 3D shot.

Illuminator
Helps focus in low light situations.

On/off slider
Activate the camera by sliding the cover down.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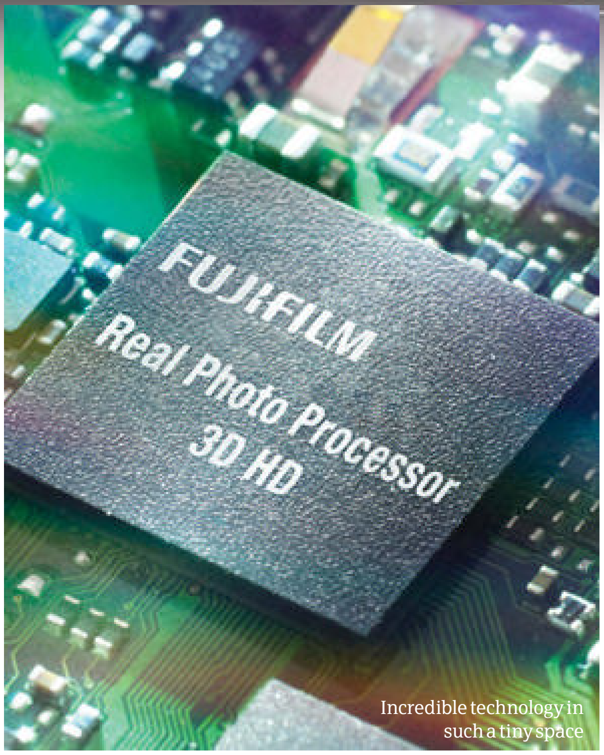


Incredible technology in such a tiny space

The statistics...

Fujifilm FinePix Real 3D W3

Manufacturer: Fujifilm

Dimensions: 124 x 27.8 x 65.9mm (4.8 x 1.1 x 2.6in)

Weight: 230g (without batteries and memory card)

Pixels: 10MP (2 x CCD sensors)

Unit price: £399

Lens: 3 x optical zoom, 35-105mm (2 x lenses)

Aperture: f3.7-4.2

ISO: 100-1600

Modes: 2D, 3D, Natural light, Natural light and with Flash, Portrait, Landscape, Sport, Night, Night (Tripod), Sunset, Snow, Beach, Underwater, Party, Anti-Blur ADV

LCD: 3.5" lenticular

THE PERFECT 3D PICTURE

The dos and don'ts for taking a 3D picture to blow you away…

Things to shoot…

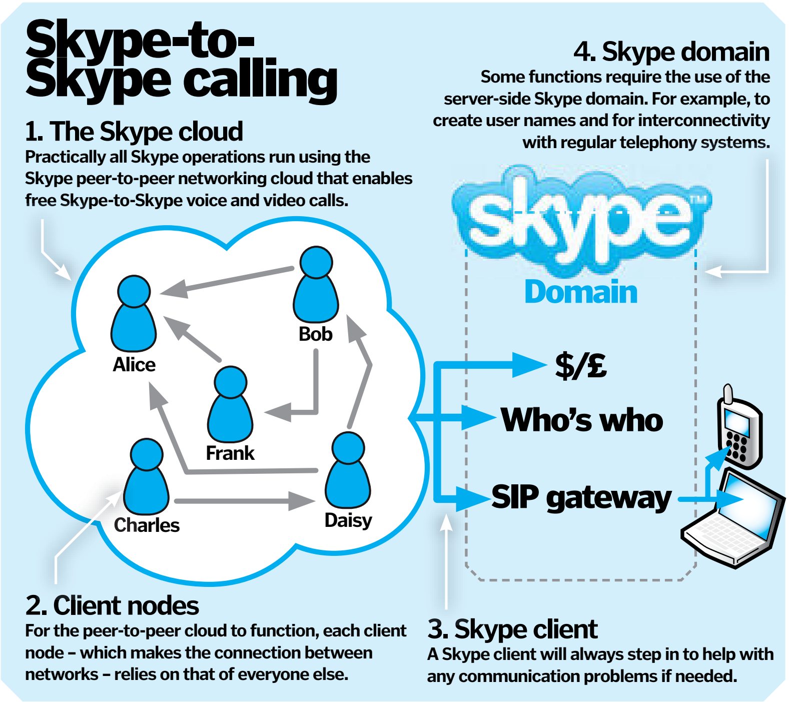
- ☑ Landscape images
- ☑ Subjects ranging from 3-200m
- ☑ One or two people
- ☑ Fountains, water or water features
- ☑ Bubbles, confetti etc

An image with layers will help create a great picture

Things NOT to shoot…

- ☒ Vertical /portrait orientation
- ☒ Close-ups (under 1m)
- ☒ Long distance landscapes
- ☒ Subjects far from background
- ☒ Groups of people
- ☒ Night scenes
- ☒ Geometric patterns
- ☒ Fine detail
- ☒ Subject too small in frame

Close-ups won't work well on a 3D camera



Skype-to-Skype calling

1. The Skype cloud
Practically all Skype operations run using the Skype peer-to-peer networking cloud that enables free Skype-to-Skype voice and video calls.

2. Client nodes
For the peer-to-peer cloud to function, each client node – which makes the connection between networks – relies on that of everyone else.

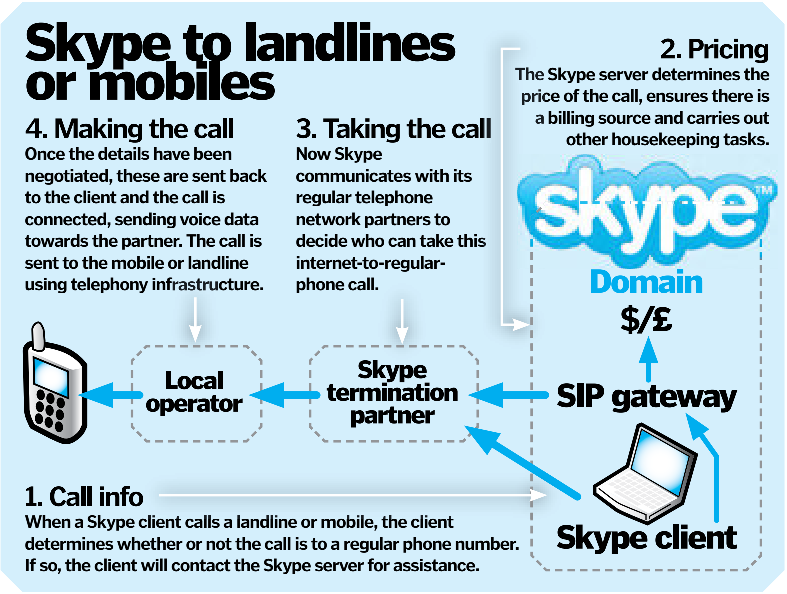
3. Skype client
A Skype client will always step in to help with any communication problems if needed.

4. Skype domain
Some functions require the use of the server-side Skype domain. For example, to create user names and for interconnectivity with regular telephony systems.

Skype explained

How peer-to-peer freeware enables us to make and receive voice and video calls

Voice over Internet Protocol (VOIP) is a growing method of communication whereby analogue audio signals (those heard when you put a traditional phone against your ear) can be turned into digital data transmittable over the internet. The Skype cloud network enables two people using Skype with a built-in microphone, a webcam and an internet connection to chat for free over the internet to and from anywhere in the world. There are also pay-for services, available outside the Skype cloud network, that enable you to either call a non-Skype user's landline or mobile, or alternatively you can be leased an 'online phone number' on which your non-Skype-using friends can call you.



Skype to landlines or mobiles

1. Call info
When a Skype client calls a landline or mobile, the client determines whether or not the call is to a regular phone number. If so, the client will contact the Skype server for assistance.

2. Pricing
The Skype server determines the price of the call, ensures there is a billing source and carries out other housekeeping tasks.

3. Taking the call
Now Skype communicates with its regular telephone network partners to decide who can take this internet-to-regular-phone call.

4. Making the call
Once the details have been negotiated, these are sent back to the client and the call is connected, sending voice data towards the partner. The call is sent to the mobile or landline using telephony infrastructure.

Digital versus optical zoom

Cameras that can crop and enlarge images just like the best photo-editing software

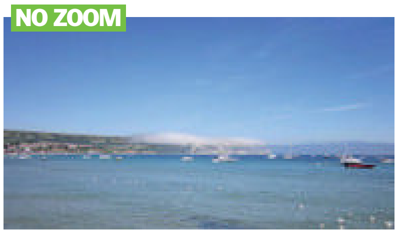
In digitally zoomed images, the number of pixels is the same as for an un-zoomed image so the software spreads out the pixels from the crop, then fills in the spaces by predicting what colour they should be.

The camera's software runs an interpolation algorithm to guess how to fill the gaps, based on what's going on in the bordering pixels. The quality achieved varies – some digitally zoomed images look fine, others can be very fuzzy.

Optical zooms use moveable lenses, like traditional film cameras. The optical zoom is operating when your camera whirs (hence 'zzzoom'), moving the lens in or out of the camera. The image is magnified on the digital camera's sensor (the chip that converts light into code to form pixels).

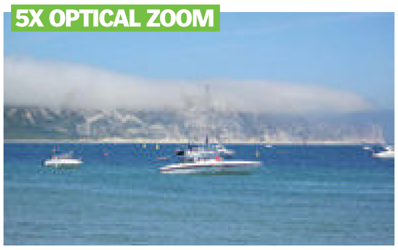
Optically zoomed photos are much sharper because all pixel colours are created from the light hitting the sensor, rather than the software's guesswork.

NO ZOOM



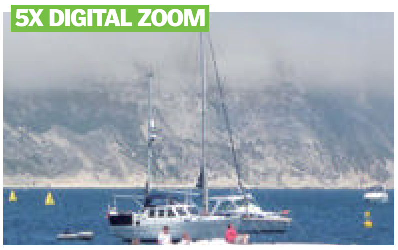
In order to get in closer the photographer will need to zoom in.

5X OPTICAL ZOOM



Using the optical zoom, the photographer gets a sharper, magnified view of the image.

5X DIGITAL ZOOM



A digital zoom crops the original image and instead of magnifying, it spreads out the same number of pixels over a larger area, using software to fill in the gaps.

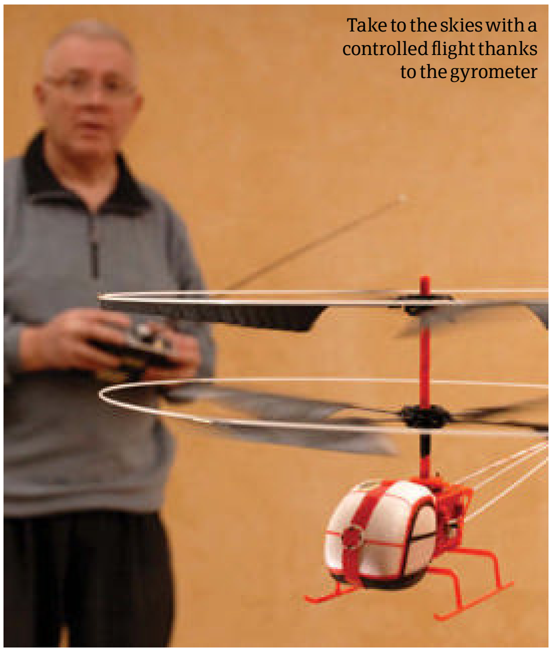
Remote-control helicopters

How these gadgets apply physics and technology used in real helicopters to move in the air

To fly a remote-control helicopter, the controls in the hands of the pilot transmit signals to a receiver on the toy when one of the joysticks is moved. This signal is a series of short pulses sent as radio waves on a specific frequency to the helicopter. The receiver processes these wave pulses and commands the motors associated with the signal to activate accordingly.

Modern remote-control helicopters typically use two joysticks to allow for user-controlled movement. The left stick controls the motors for up and down motion of the helicopter as well as the rudder (yaw motion), moving the helicopter left and right. The right stick controls the banking movements in 360 degrees.

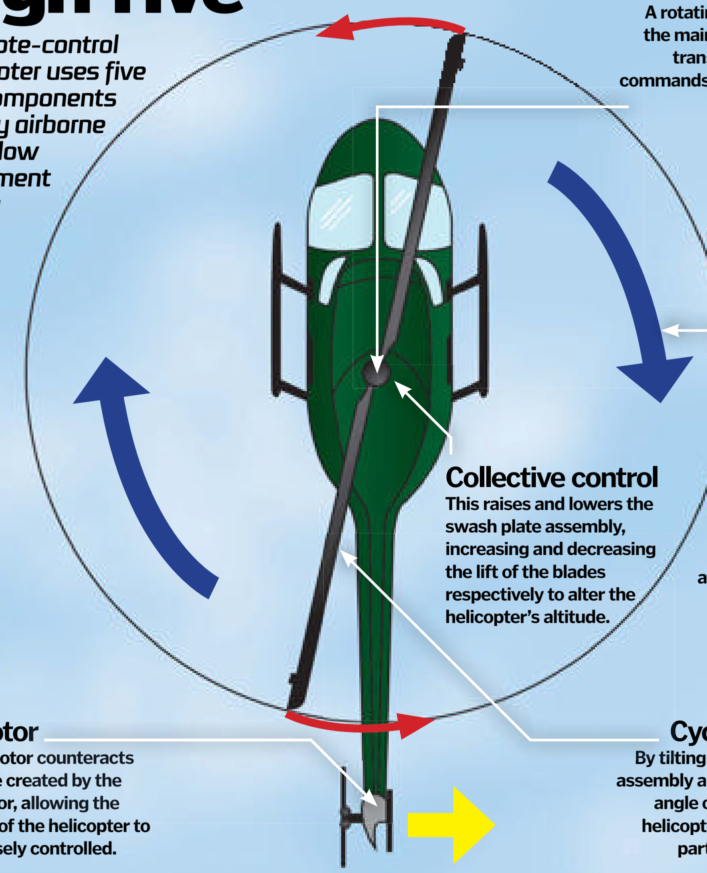
The main rotor of the helicopter, located above the body, consists of two or more blades. The rotor generates lift by rotating the angled blades and pushing air downwards. Depending on the type of helicopter, it will spin from 1,500 to 3,000 rotations per minute. The tail rotor counteracts the force of the main rotor by spinning up to six times faster, allowing the helicopter's rotation to be controlled. An automated interior gyrometer adjusts the pitch of the tail rotor to hold the helicopter steady in the air.



Take to the skies with a controlled flight thanks to the gyrometer

High five

A remote-control helicopter uses five key components to stay airborne and allow movement during flight



Swash plate assembly
A rotating disc between the main rotor and body translates the pilot's commands into the motion of the blades.

Main rotor
The tilted blades rotate to produce lift, with different amounts generated by changing the speed and pitch angle of the rotor assembly.

Collective control
This raises and lowers the swash plate assembly, increasing and decreasing the lift of the blades respectively to alter the helicopter's altitude.

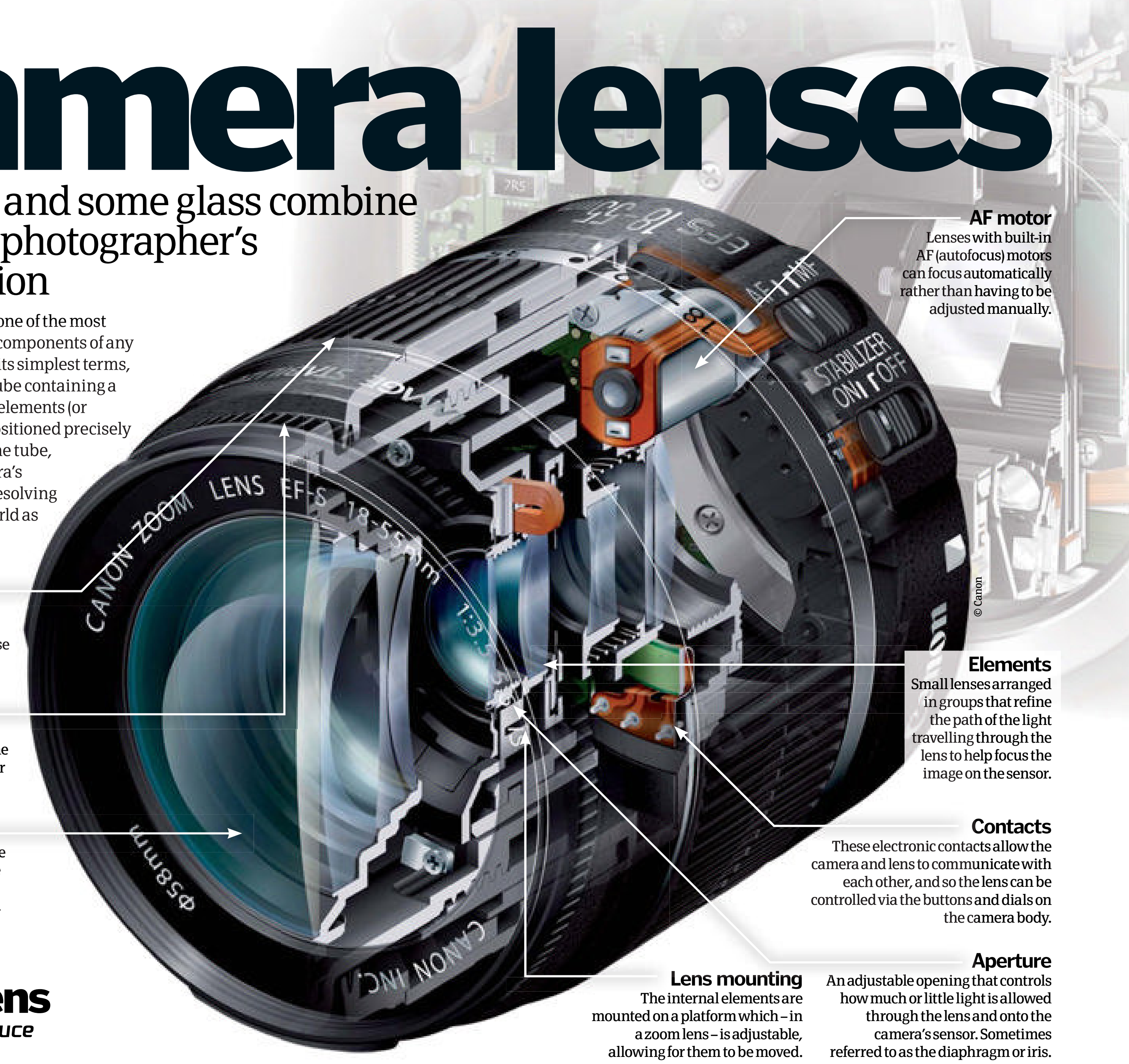
Tail rotor
The tail rotor counteracts the force created by the main rotor, allowing the rotation of the helicopter to be precisely controlled.

Cyclic control
By tilting the swash plate assembly and changing the angle of the blades the helicopter can move in a particular direction.

Camera lenses

How a tube and some glass combine to resolve a photographer's creative vision

The lens is one of the most important components of any camera. In its simplest terms, a lens is a tube containing a set of glass elements (or lenses), each of which is positioned precisely to channel light through the tube, focusing it onto your camera's sensor or film plane, and resolving an image of the outside world as a result.



© Canon

Zoom ring
Only found on a zoom lens – rotating this moves the lens elements to increase or decrease the lens's magnifying power.

Focusing ring
The photographer turns this to fine-tune the space between the front and rear elements in order to focus the image.

Front element
The point where light enters the lens. Front elements often have a special coating to reduce problems like ghosting or flare.

AF motor
Lenses with built-in AF (autofocus) motors can focus automatically rather than having to be adjusted manually.

Elements
Small lenses arranged in groups that refine the path of the light travelling through the lens to help focus the image on the sensor.

Contacts
These electronic contacts allow the camera and lens to communicate with each other, and so the lens can be controlled via the buttons and dials on the camera body.

Lens mounting
The internal elements are mounted on a platform which – in a zoom lens – is adjustable, allowing for them to be moved.

Aperture
An adjustable opening that controls how much or little light is allowed through the lens and onto the camera's sensor. Sometimes referred to as the diaphragm or iris.

Inside a camera lens

The parts that produce the ideal picture

Optical or digital zoom

If you look at any compact or superzoom digital camera's specifications, chances are it'll state values for both optical and digital zoom capability. Optical zoom refers to the ability of a camera's lens to shift its internal elements, magnifying the subject you're trying to photograph as the lens zooms to the telephoto (longest) end of its focal range. All non-fixed focal length DSLR lenses zoom optically. Digital zoom, on the other hand, involves no physical zooming mechanism at all; rather the camera crops into your image, making your subject appear to fill more of the frame. Overall image quality is reduced as the camera makes up (interpolates) pixels to create the impression of magnification, which may produce less-than-satisfactory results.

Wide
The wide-angled shot ready for some serious zooming!

Optical
Keeps quality high, found on all non-fixed focal length DSLRs.

Digital
Focuses in-depth on a specific area, but loses overall quality.

3 x images © Josie Reavely

Head to Head CAMERA LENSES

GOOD

1. 18-250mm f/3.5-6.3 DC OS HSM

Costing £573, this lens covers a decent focal range but a non-fixed aperture means less light-gathering ability as you zoom.

BETTER

2. 50-500mm f/4.5-6.3 DG OS HSM

Priced at £1,400 this telephoto lens also spans a wide focal range, but it's heavy, and can suffer from loss of sharpness.

BEST

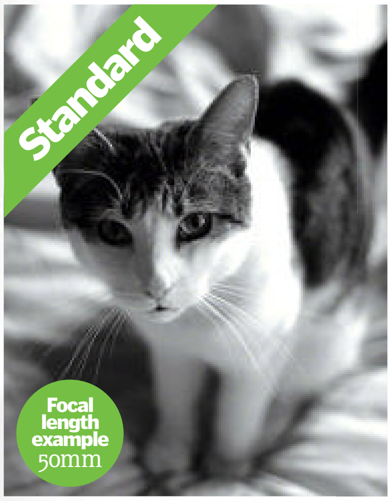
3. 70-200mm f/2.8 EX DG MACRO HSM II

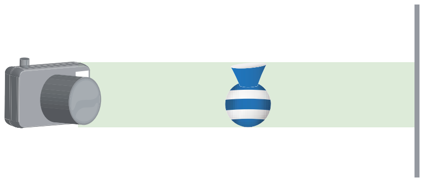
This impressive lens costs £817 and has wide fixed maximum aperture, meaning it stays the same even if you zoom in.

DID YOU KNOW? *The glass used for lenses must be completely colourless*

Lens choices

Knowing which lens to use for which shot is the key to achieving the perfect photograph



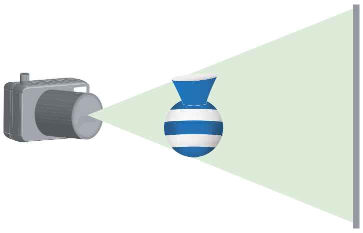


A standard or 'normal' lens typically has a focal length equal to the diagonal of the focal plane, which is around 35mm on a 'cropped' (APS-C) sensor DSLR or 50mm on a full frame camera. The front element of a standard lens is fairly flat, so light is not significantly bent internally, and the image projected onto the sensor should roughly fill it, without any overlap. The standard lens is considered ideal for portraits as – when engineered correctly – they generate little, if any, distortion and tend to perform well in low light.

USE LENS IF/WHEN...

... trying to capture flattering portraits with minimal distortion

Wide-angle
Focal length example
24mm



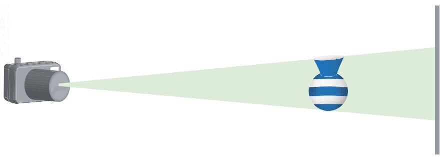
Wide-angle lenses have a short focal length (roughly less than 35mm on a full frame camera) and have curved front elements, which give them a wide angle of view. The fact that the glass at the front of the lens is curved outwards means the light rays enter the front element at a sharper angle, spreading light across a smaller area of the camera's sensor and therefore producing a wider angle of view in your final image. This has the effect of allowing the lens to 'see' more around it and exaggerating the wide perspective of a scene.

USE LENS IF/WHEN...

... photographing groups of people, tall buildings or sweeping landscapes

Telephoto
Focal length example
200mm

©3 x images © Josie Reavely



A telephoto lens covers the longer end of the focal ranges – with around 200-300mm being the most popular among enthusiasts, but professionals often use much longer optics. The front group of elements in a telephoto lens gather and project light onto a rear group of elements, which magnify the image transmitted and spread it across a wider area of the image sensor, creating a magnified version of your distant subject. This design allows the lens elements to be closer together, helping to keep the physical length of the lens barrel compact in relation to its focal length.

USE LENS IF/WHEN...

... you have to shoot from a distance, such as at sporting events or when photographing wildlife and candid portraits

Other lenses

Macro

Macro optics are highly specialised lenses with powerful magnification capabilities. They feature a flat image plane and, usually, very high-grade glass elements which are highly corrected to minimise any distortion. Most produce a 1:1 (life-size) reproduction of a subject, although some can magnify by up to five times.

USE LENS IF/WHEN...

...you want to make small things look big

Fisheye

A fisheye lens is an extreme version of a wide-angle lens. The front element is bulbous, literally like a fish eye, which diverges light. These lenses produce a great deal of distortion, with objects being 'pulled' away from the centre of the frame, but give a very wide angle of view – often around 180-degrees or more.

USE LENS IF/WHEN...

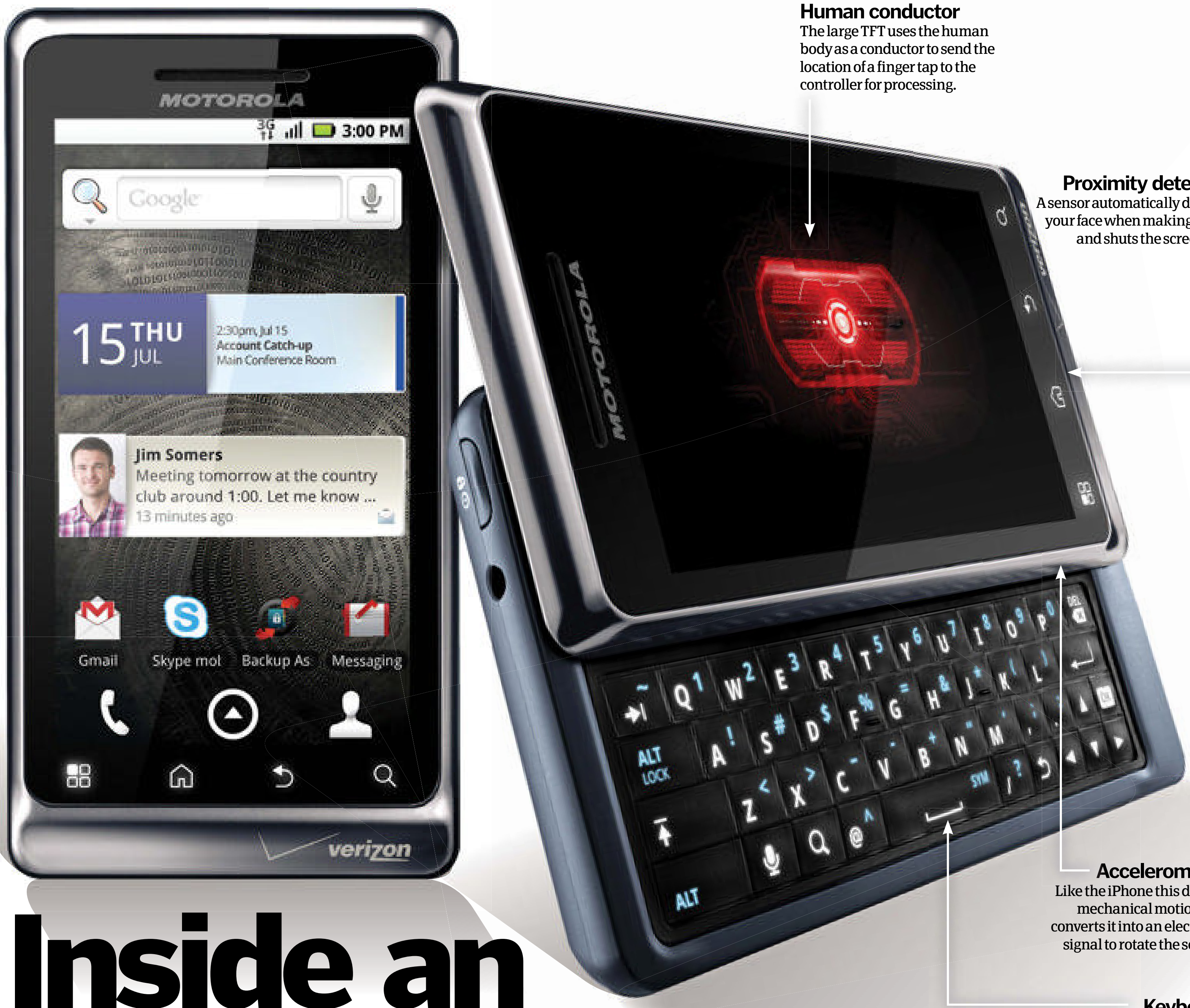
...you want everything in your shot, or for comic effect in portraits

Teleconverter

Teleconverters are basically tubes that contain predominantly diverging lens elements. These are attached to your existing lens and increase its magnification power, allowing you to zoom further with a telephoto lens or magnify your subject more with a macro optic, for example. The downside is they reduce the lens's maximum aperture and can reduce image quality.

USE LENS IF/WHEN...

...your telephoto lens isn't quite long enough to fill the frame with your subject


MOTOROLA
3:00 PM
Google
15 THU JUL
2:30pm, Jul 15
Account Catch-up
Main Conference Room
Jim Somers
Meeting tomorrow at the country club around 1:00. Let me know ...
13 minutes ago
Gmail
Skype mol
Backup As
Messaging
verizon
MOTOROLA

Human conductor
The large TFT uses the human body as a conductor to send the location of a finger tap to the controller for processing.

Proximity detector
A sensor automatically detects your face when making a call and shuts the screen off.

Accelerometer
Like the iPhone this detects mechanical motion and converts it into an electronic signal to rotate the screen.

Keyboard
The main point of difference over the iPhone is the pull-out Qwerty keyboard.

Inside an Android phone

Discover the awesome technology contained within today's Android smartphones

The Motorola Droid 2 is a smartphone that attempts to do everything in the most technologically advanced way. It comes with multiple features and clever implementations that allow everything to happen in a very small space. The large capacitive TFT display crams in 409,920 pixels and uses the human body as a conductor to send the location of a finger tap to the controller for processing. This makes using the device feel much more natural than using a stylus, but it does mean that some preciseness is lost.

A proximity sensor automatically detects your face when making a call by emitting an electromagnetic field to turn the screen off and on and an accelerometer detects mechanical motion and converts it into an electronic signal to rotate the screen automatically as you move it.

For mobile data EVDO rev. A is included which combats network congestion and noise and although it is based on 3G technology, it allows theoretical data speeds of up to 3Mbit/s. The camera is blessed with image stabilisation which senses when the camera is moving and automatically takes a picture only when the phone is stable enough to produce a sharp image. It also includes an auto focus feature that uses a sensor, motor and a control system to do the focusing for you while retaining the ability to manually focus on a selected area. And these are just a few of the hundreds of clever features onboard.

5 TOP FACTS ANDROID DEVICES

HTC Desire

1 The HTC Desire offers powerhouse specifications in a modern and stylish form factor that will appeal to both teenagers and hardened smartphone users alike.

Samsung Galaxy S

2 Samsung has made a big splash in the Android world with the Galaxy S. The superb 4-inch super-AMOLED screen is the definitely the highlight here.

LG Optimus GT540

3 You can now buy a 3G-enabled Android smartphone for under £100. The three megapixel camera, GPS and social networking make this the ideal entry model for new users.

Sony Ericsson X10 Mini

4 No smartphone has ever been as small as the X10 Mini offered by Sony Ericsson, but remarkably it still offers the full Android experience in a tiny space.

Dell Streak

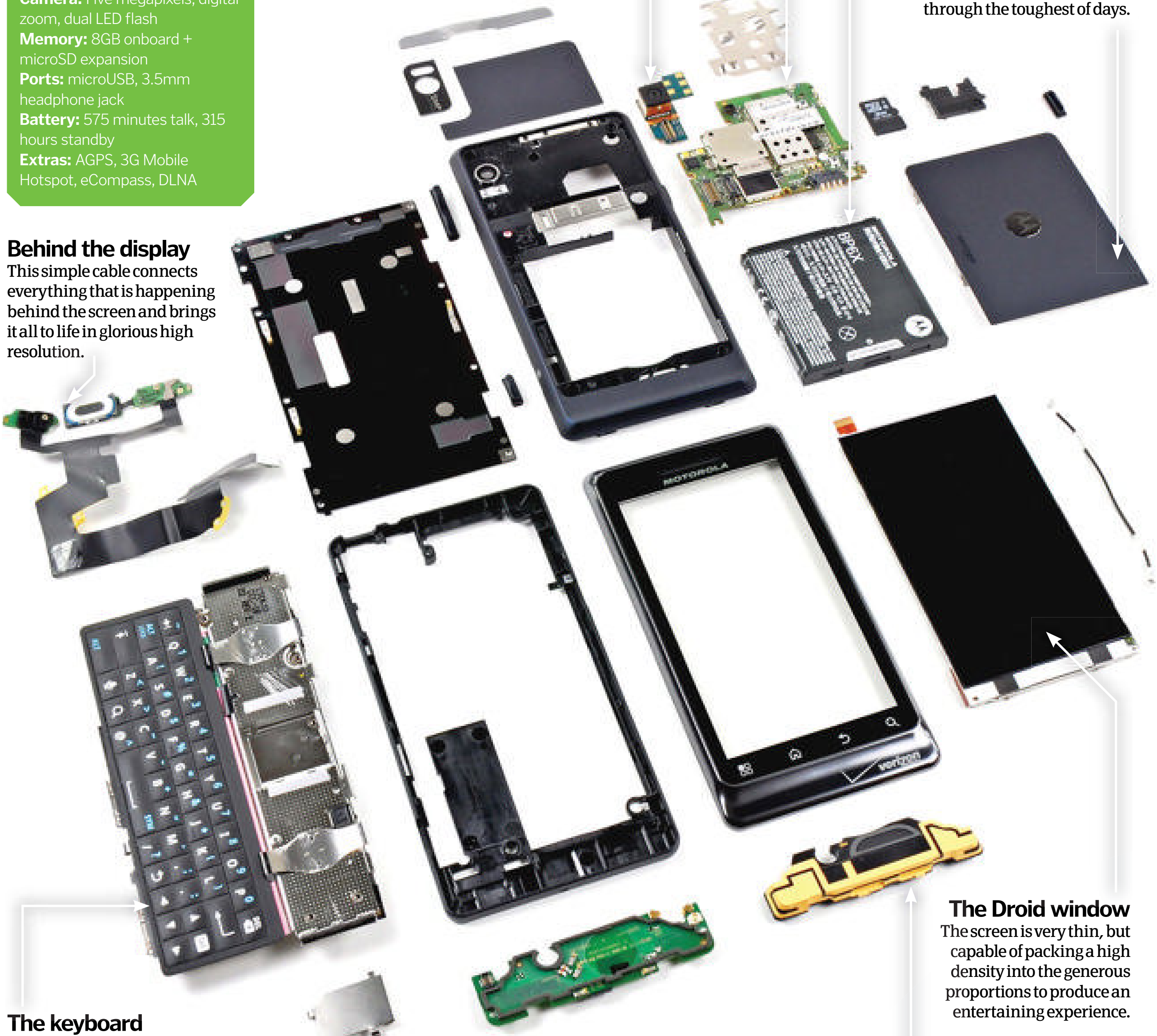
5 The Dell Streak is the first of a new breed of device that sits in between a smartphone and a tablet. With a 5-inch screen it retains portability yet offers a more complete experience.

DID YOU KNOW? *The Droid 2 supports DNLA along with 8,000 other devices. This allows you to share photos, music and video*

The Statistics

Motorola Droid 2

Dimensions: 60.5 x 116.3 x 13.7mm
Weight: 169g
Display: 3.7in TFT, 480 x 854 pixels
Processor/speed: 1 GHz
Camera: Five megapixels, digital zoom, dual LED flash
Memory: 8GB onboard + microSD expansion
Ports: microUSB, 3.5mm headphone jack
Battery: 575 minutes talk, 315 hours standby
Extras: AGPS, 3G Mobile Hotspot, eCompass, DLNA



Camera

It is hard to believe that the almost microscopic camera module is capable of DVD-quality video recording.

The engine

The motherboard is tiny, but still manages to house the main processor, 512MB of RAM, compass, microphone and a secondary microphone to clear up background noise.

Battery

The 1390 mAh battery is capable of supplying over 500 minutes of talk time and more than 300 hours of standby. That should get you through the day.

Protection

The metal battery cover not only looks good, but provides extra protection to help the Droid 2 get through the toughest of days.

Behind the display

This simple cable connects everything that is happening behind the screen and brings it all to life in glorious high resolution.

The keyboard

The keyboard makes full use of the extended width on the Droid 2 and adheres closely to the standard keyboard layout found in larger computers.

Under the shell of the Droid 2

The Droid window

The screen is very thin, but capable of packing a high density into the generous proportions to produce an entertaining experience.

A clever speaker

The speaker has a gold sticker attached to it which also doubles as a cleverly implemented internal antenna.

Droid 2 vs iPhone 4

	iPhone 4	Droid 2
Screen size	3.5in	3.7in
Processor	1 GHz	1 GHz
Memory	16GB / 32GB	8GB
Apps	225,000 +	70,000 +
Camera	5MP	5MP
Battery	420 minutes talk, 300 hours standby	575 minutes talk, 315 hours standby

Overall...

With thousands of apps available for each, and similar specifications all round, your choice will really depend upon what you actually need most: a hardware keyboard or a superior screen. Our vote goes to the iPhone 4 for its unmatched ease of use, but only by a whisker.

Learn more

For more info and images of the exposed Droid 2, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.

ifixit

70,000 Droid apps

It is easy to be seduced by the hundreds of thousands of apps available for the iPhone, but with more than 70,000 available for the Droid you will not be found wanting. Most people use fewer than ten apps regularly so anything above 5,000 is more than acceptable. Of all the smartphone platforms competing in the crowded market, Android is the only real competitor for the iPhone in terms of app numbers and quality and could easily head the field in the future.

3:29 PM
ANDROID
market
Apps
Games
Verizon

Noise-cancelling headphones

The way we listen to music has changed dramatically in recent years, making noise-cancelling headphones more important… and expensive

Noise-cancelling technology is not to be confused with noise reducing, although the best examples use a combination of both. Noise reducing – a 'passive' solution that relies on insulating the ears against unwanted sound – tends to be cheaper and applies to both earphones and headphones. Noise cancelling, meanwhile, employs Active Noise Control (ANC) to create sound waves of the opposite frequency to those you wish to block out – also known as anti-noise. This is achieved with positioning tiny microphones close to each earpiece, fast-reacting amplification circuitry to create the anti-noise and a battery for power.

Most studies indicate that ANC is more effective with continuous low-frequency sounds (such as traffic) than rapidly changing mid-frequency ones (such as human conversation) and may also create its own high-frequency hiss. Design-wise they can either sit around or on the ear with prices as high as £400 a pair.

Thermograms show infrared radiation based on an object's temperature

What is infrared thermal imaging?

Used in reality cop shows, how does this clever imaging system work?

Infrared thermal imaging, or infrared thermography, is a bit of a mouthful, but the concept behind it is much more simplistic. Thermographic cameras take a picture of the infrared radiation emitted by the subject based on its thermal conditions, invisible to the naked eye. The amount of radiation that is released increases with temperature, and this is what can be seen in a thermogram. For example, this make it possible to isolate a human in an otherwise cool environment, even in the dark.

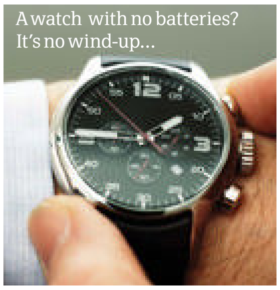
The cameras themselves look a lot like your regular camcorder. Most thermograms that you'll see will be in colour, where cooler objects are represented by blues and purples, and warmer objects by oranges and yellows, but sometimes they are represented in greyscale, where white represents hot and black represents cool.

Thermography is widely used by security and emergency services. For example, during the swine flu pandemic, airport staff used thermographic cameras to detect possible carriers.

How do batteryless watches work?

Batteryless watches provide an environmentally friendly way of keeping track of time

Relying purely on the movement of its wearer, the batteryless watch allows time keeping without the normal damaging effects to the environment of battery disposal. This remarkable feat is achieved by a movement-sensitive weight encased within the timepiece which, when forced to move back and forth, causes a micro-generator to begin spinning and produce electrical energy. This energy is then stored in a capacitor for slow and gradual release over time into the watch's integrated circuit (which powers its other components), keeping it ticking even during periods of inactivity. In fact, powered by this transformation of kinetic energy, a batteryless watch can continue keeping time without movement for up to two weeks, depending on the make and model of course.


A watch with no batteries? It's no wind-up…

DID YOU KNOW? In addition to kinetic energy, certain models of battery-free watches can actually be powered by light.

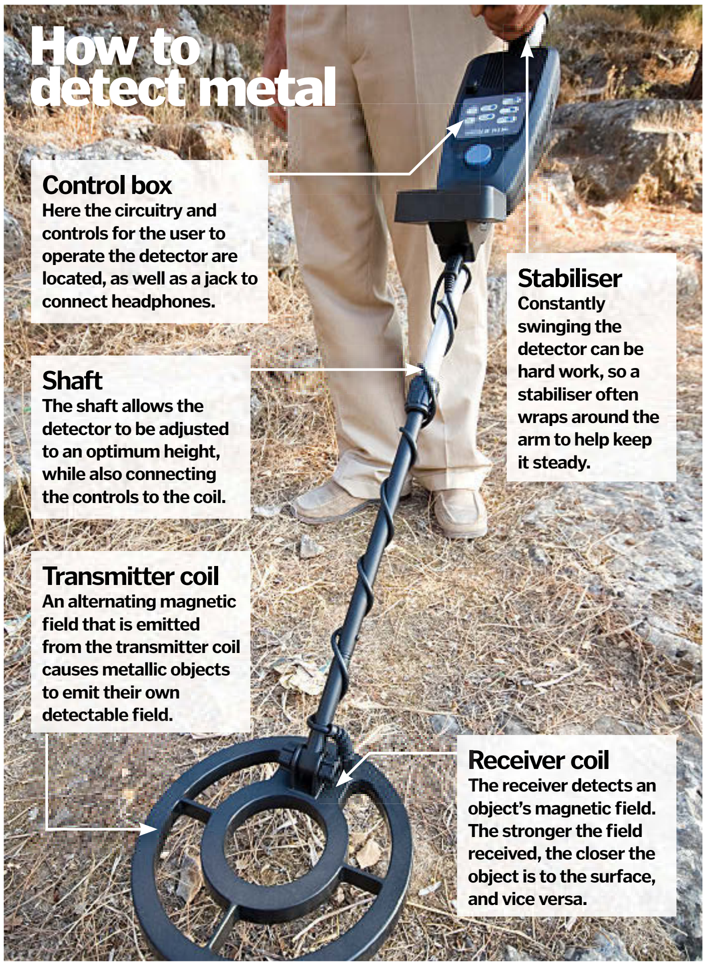
Metal detectors

Find out how to locate buried treasure using magnetism

The most common metal detector uses a Very Low Frequency (VLF) technology to search for hidden objects. It employs one of the basic laws of electromagnetism: that an object in an alternating magnetic field (switching from north to south polarity) will create an oscillating field of its own in opposition. A transmitter coil emits this field, switching at a frequency of thousands of times per second. A device known as a magnetometer within a receiver coil can detect magnetic pulses pushed upwards from the object underground in response, and alert the user of the metal detector via a beep or on screen.

By cleverly employing a process known as phase shifting, the VLF detector can deduce what sort of object is beneath the surface. This method works by calculating the time difference between the frequency of the transmitter's field and the corresponding response from underground. This all depends on how easily the object conducts electricity, and once this is known its composition can then be approximated.

How to detect metal



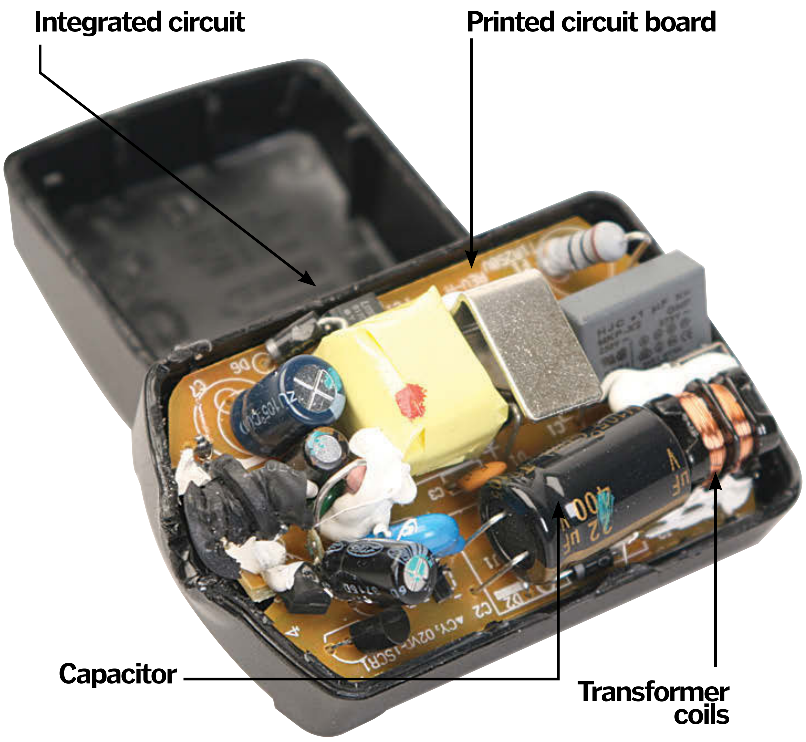
Control box
Here the circuitry and controls for the user to operate the detector are located, as well as a jack to connect headphones.

Shaft
The shaft allows the detector to be adjusted to an optimum height, while also connecting the controls to the coil.

Transmitter coil
An alternating magnetic field that is emitted from the transmitter coil causes metallic objects to emit their own detectable field.

Stabiliser
Constantly swinging the detector can be hard work, so a stabiliser often wraps around the arm to help keep it steady.

Receiver coil
The receiver detects an object's magnetic field. The stronger the field received, the closer the object is to the surface, and vice versa.



What's goes on inside your mobile phone charger?

The everyday device that provides you the power to talk and text

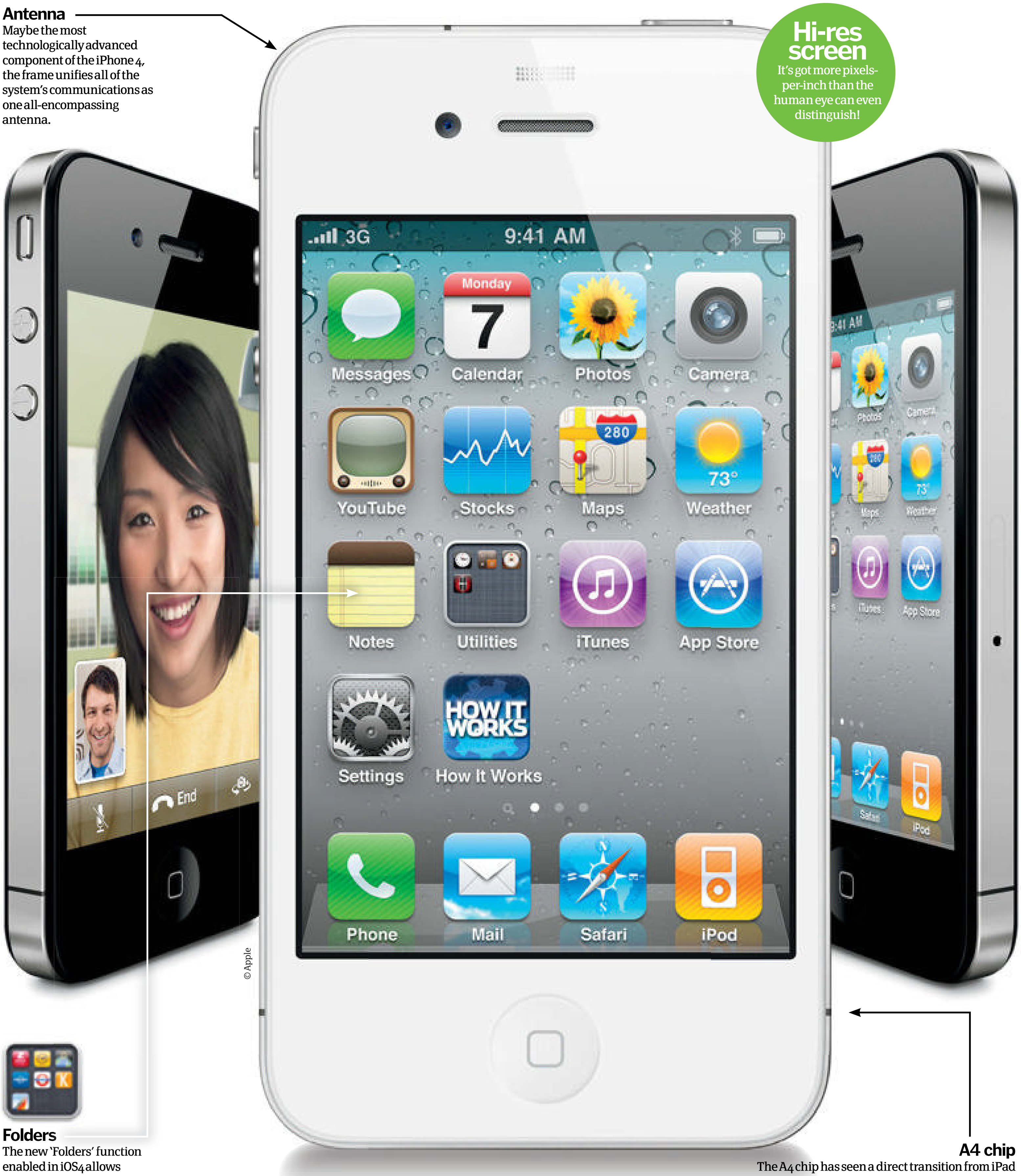
Small rechargeable batteries power your mobile phone. Three types of rechargeable battery have been used in the past: the earliest were nickel cadmium (NiCd) and nickel metal hydride (NiMH) batteries, while the latest are lithium-ion (li-ion) batteries. NiCd and NiMH batteries suffer from something called the 'memory effect' and need to be regularly discharged fully before being charged again. Li-ion batteries are immune to the memory effect, and can run for twice as long as an NiMH before it needs to be recharged.

All these batteries require recharging with a DC voltage supply. This is supplied by a mobile phone charger, which is basically an adaptor plug that fits into the AC voltage electrical outlet socket of your home or office. This uses a transformer to reduce the AC voltage before it is converted by a rectifier from AC to DC voltage. Running from the adaptor is a cable that fits into a socket on the phone. The phone itself contains charging filter circuitry before the power is sent to the battery itself.

Mobiles are always supplied with a charger as different models have different voltages and connection sockets. In 2009, 17 manufacturers agreed to a standard charger design that would have a micro-USB connector. Fortunately these will be more energy efficient and a charger will no longer need to be sold with every phone.

DID YOU KNOW? In developing countries where electricity is not always available, people have to make special trips to professional gadget charger dealers to get their phone recharged.

Antenna
Maybe the most technologically advanced component of the iPhone 4, the frame unifies all of the system's communications as one all-encompassing antenna.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How It Works
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iPod
End

© Apple

Hi-res screen
It's got more pixels-per-inch than the human eye can even distinguish!

Folders
The new 'Folders' function enabled in iOS4 allows apps to be grouped in clusters for ease of access.

A4 chip
The A4 chip has seen a direct transition from iPad to iPhone 4 and provides unparalleled speed and power in comparable handheld devices.

5 TOP FACTS NEW FEATURES

FaceTime

1 The forward-facing 5MP camera enables the new and exciting FaceTime video calling feature, allowing high-quality face-to-face visual communication.

Glass

2 Both the front and back feature Apple's special optical grade glass, a chemically strengthened alkali-aluminosilicate that is 20-30 times harder than plastic.

Retina Display

3 The brand-new screen on the iPhone 4 – referred to as the Retina Display – has 326 pixels-per-inch, which exceeds what human eyes can actually detect.

A4 chip

4 The iPhone 4 features the custom built A4 chip debuted in the Apple iPad. It is a package-on-package system that is quicker than those of previous iPhone iterations.

Tapered design

5 The new design is not just for aesthetic purposes but also allows for far greater reception and service as it acts as an antenna for the phone's communications systems.

DID YOU KNOW? *Within hours of the iPhone 4's release, complaints surfaced over loss of reception when held in a certain way*

Inside an iPhone

Discover what goes on beneath the surface of Apple's latest and greatest iPhone to see what new features and technology it brings to the smartphone foray

Apple is a company that will never undersell anything. Its strict privacy, powerful marketing and lust for innovation pushes the company to incredible levels of enthusiasm with everything it does. Even, for instance, when it made the upgrade from iPhone 3G to iPhone 3GS. This drive is even more evident in the recently released iPhone 4, Apple's latest iteration of the iPhone that was embroiled in an ongoing leak/raid/court saga, the consequences of a prototype model being lost, found and made public way before Apple's official unveiling. The furore that followed was not surprising as, after all, this was the successor to the smartphone throne and offered a faster, more powerful system and radical aesthetic redesign of the most hyped phone on the planet. So find out just what was so special about the iPhone and what goes on inside one.

© Apple

Display

The iPhone 4's new screen has 326 pixels-per-inch – bearing in mind the human eye loses the ability to distinguish at 300ppi – and it also contains the new IPS technology which increases the viewing angle and is present on the iPad. The screen also contains 78 per cent of the number of pixels of the iPad but in a 3.5-inch screen. Apple calls this a Retina Display and is specially designed to make text as easy to read as traditional print. Covering the screen is a glass panel constructed of Corning Gorilla Glass, a chemically strengthened alkali-aluminosilicate that is 20-30 times harder than plastic.

The display is covered by Apple's special optical grade glass

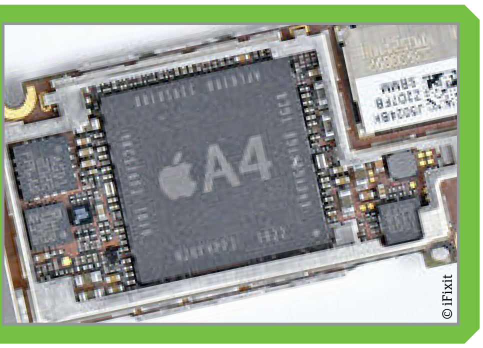
© Apple

Tapered frame

Apple has integrated the UMTS, GSM, GPS, Wi-Fi, and Bluetooth antennas into the stainless steel inner frame. The dual-purpose stainless steel inner frame/antenna assembly addresses possibly the two biggest flaws concerning previous iterations of the iPhone: continuous dropped calls and lack of reception. Apple has gone a step further though and tuned the phone to utilise whichever network band is less congested or has the least interference for the best signal quality.

A4 chip

The iPhone 4 is powered by the same A4 chip as debuted in the Apple iPad, an ARM processor featuring package-on-package construction. The A4 is made from custom silicone and is a complete system on a chip, with 256MB of RAM on top of it in order to deliver enhanced performance over previous models. The chip will allow for the iPhone 4's new features such as the latest operating system (iOS4) and other new abilities like 'Folders' and 'Multitasking' to be taken advantage of greatly, delivering raw speed and huge processing power.



© iFixit

Face Time

A step-by-step guide to making a video conference call with the iPhone 4's FaceTime feature

1. Commerce

Well, both parties need an iPhone 4, so you and your friends will need to buy one before FaceTime can commence for anyone.

2. Box

FaceTime works right out of the box with no need to set up a special account or screen name, so just un-box the phone and go to your home screen.

3. Contacts

Next, find the entry in your contacts of the person you want to call and once brought up simply tap the FaceTime button. Or, if you are already in audio contact with the person, simply tap the FaceTime button.

4. Invitation

Either way, once the FaceTime button is pressed, the contact then receives an invitation via pop-up on their iPhone 4, which s/he can then accept or refuse (the latter is probable if you are known to steal their French fries).

5. Link

As soon as the person accepts the FaceTime invitation the direct video link begins, working seamlessly in both portrait and landscape modes.

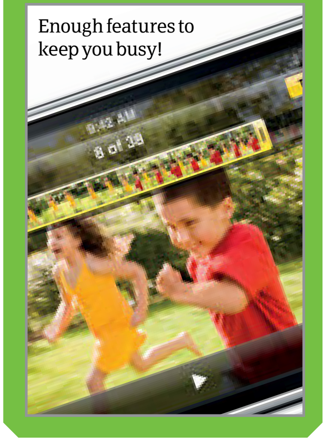
iPhone anatomy

More than the sum of its parts… which are many and highly intricate

It is a sad sight to see one of Apple's beautiful products broken, laid out on a table post dissection. However, in a quest to understand just how the iPhone 4 works it is a necessary evil, one that gives a fascinating insight into the technology within. SO here are the innards of Apple's latest iPhone

iOS4

The iPhone 4 comes shipped with a pre-installed version of Apple's latest operating system, iOS4. This provides over 100 new features including, among others: multitasking allows users to run favourite third-party apps and switch between them instantly without any slow down in performance or unnecessary draining of battery reserves. Folders gives the ability to group and organise apps into folders with drag-and-drop simplicity. iBooks was made possible by the fidelity of the iPhone 4's new screen, eBooks can now be browsed, bought, downloaded and read 24 hours a day. Playlists enable you to create and edit custom playlists and sync and display nested playlist folders from iTunes. Importantly, while iOS4 is available on most other iPhone models, only on the iPhone 4 are all new functions and features accessible, with previous models' specifications unable to cope with some of the more complex processing demands.

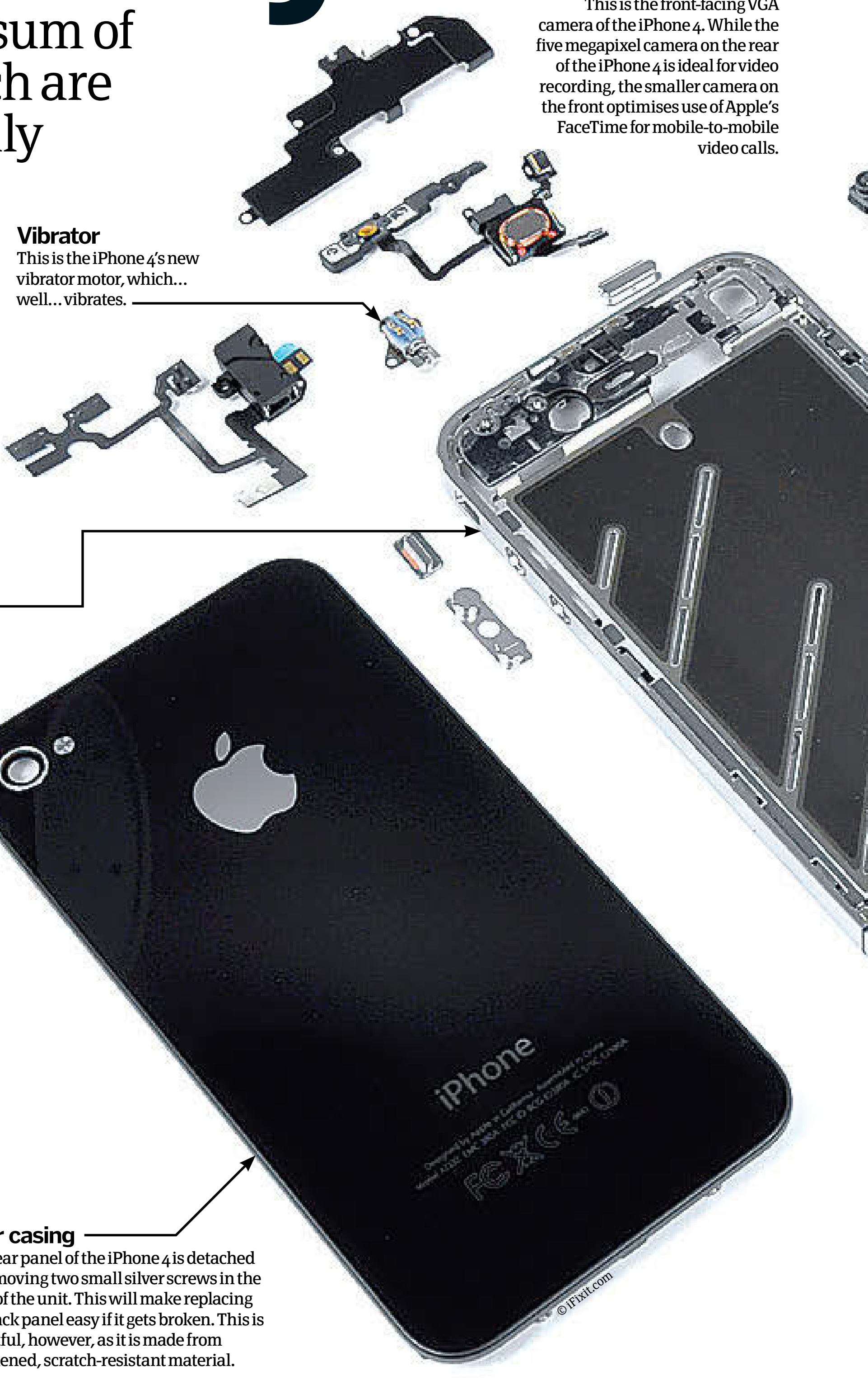


Enough features to keep you busy!

The Statistics

Apple iPhone 4

Dimensions: 115.2 x 58.6 x 9.3mm
Weight: 137g
Display: 3.5-inch, 960 by 640-pixel resolution, 326ppi
Processor/speed: 1 GHz ARM Cortex A8 core
Camera: 5MP, 720p HD, LED flash
Memory: 512MB
Ports: 3.5mm stereo headphone minijack, 30-pin dock connector
Battery: 3.7V 1420 mAh li-polymer
Extras: Apple earphones with remote and mic, dock connector to USB, USB power adapter



VGA camera
This is the front-facing VGA camera of the iPhone 4. While the five megapixel camera on the rear of the iPhone 4 is ideal for video recording, the smaller camera on the front optimises use of Apple's FaceTime for mobile-to-mobile video calls.

Vibrator
This is the iPhone 4's new vibrator motor, which… well… vibrates.

Frame
The iPhone 4's design is a dramatic departure from the aluminium and plastic found on previous iPhone models. The rugged stainless steel bezels around the iPhone 4's perimeter double as both structural supports and antennas to boost reception.

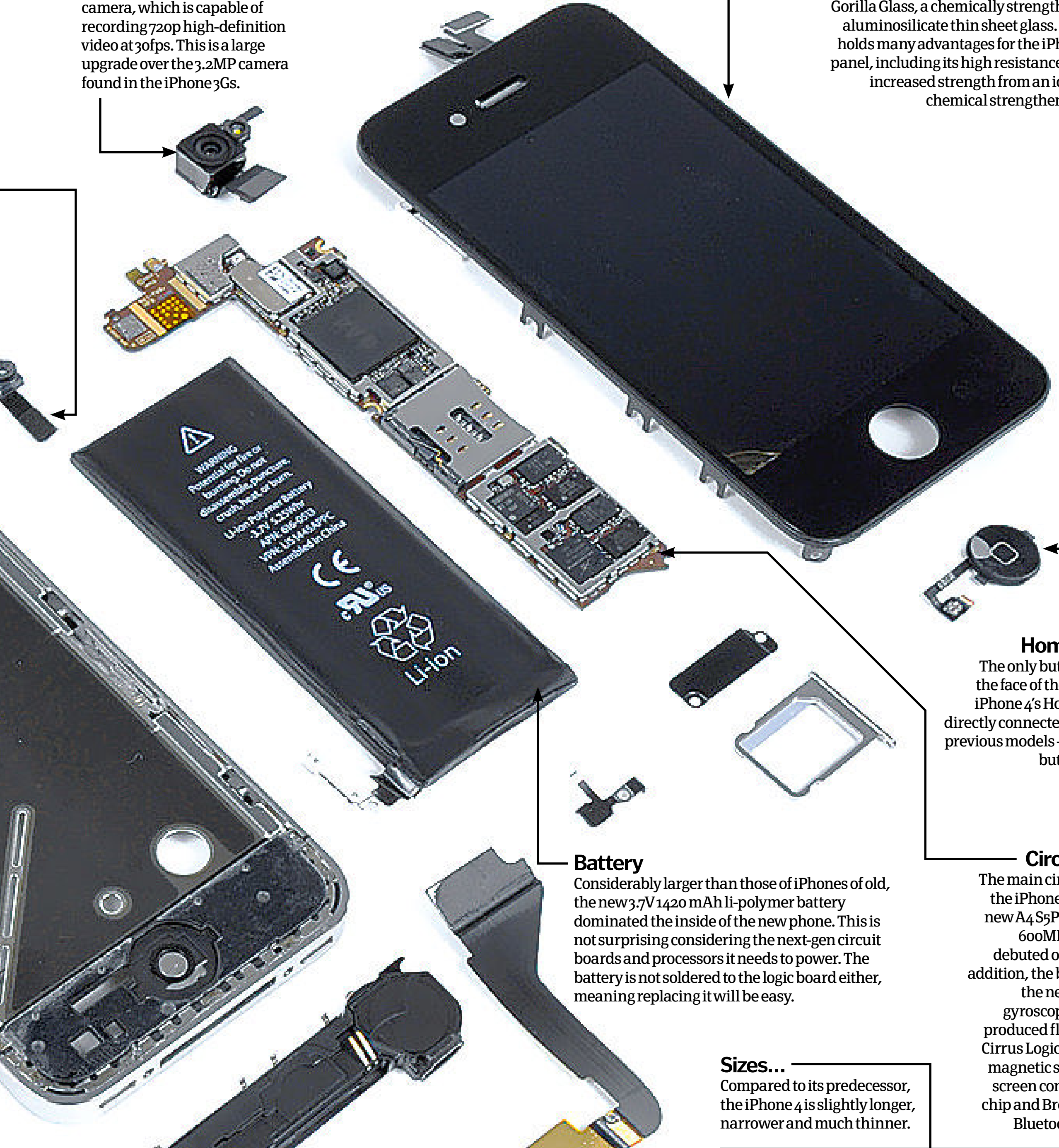
Rear casing
The rear panel of the iPhone 4 is detached by removing two small silver screws in the base of the unit. This will make replacing the back panel easy if it gets broken. This is doubtful, however, as it is made from toughened, scratch-resistant material.

© iFixit.com

THE STATS iPHONE 4

SCREEN PIXELS-PER-INCH 326
CAMERA 5MP 720p
BATTERY 3.7V 1420mAh
RAM 512MB
HDD 16-32GB
CORE 1GHz ARM Cortex A8

DID YOU KNOW? *The gyroscope in the iPhone 4 was manufactured by ST Micro for Apple and is not commercially available*



Camera
This is the phone's new wizzy 5MP camera, which is capable of recording 720p high-definition video at 30fps. This is a large upgrade over the 3.2MP camera found in the iPhone 3Gs.

Screen
The front glass panel is constructed of Corning Gorilla Glass, a chemically strengthened alkali-aluminosilicate thin sheet glass. Gorilla Glass holds many advantages for the iPhone 4's front panel, including its high resistance to wear and increased strength from an ion-exchange chemical strengthening process.

Home button
The only button again on the face of the iPhone, the iPhone 4's Home button is directly connected – unlike on previous models – to the home button's switch.

Battery
Considerably larger than those of iPhones of old, the new 3.7V 1420mAh li-polymer battery dominated the inside of the new phone. This is not surprising considering the next-gen circuit boards and processors it needs to power. The battery is not soldered to the logic board either, meaning replacing it will be easy.

Circuit board
The main circuit board of the iPhone 4 houses the new A4 S5PC100 ARM A8 600MHz processor, debuted on the iPad. In addition, the board houses the new three-axis gyroscope, Samsung-produced flash memory, Cirrus Logic audio codec, magnetic sensor, touch-screen controller, Wi-Fi chip and Broadcom GPS/Bluetooth receivers.

Sizes…
Compared to its predecessor, the iPhone 4 is slightly longer, narrower and much thinner.

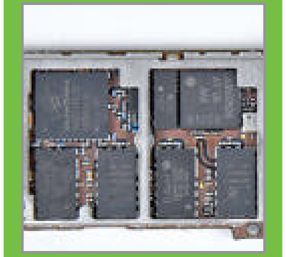
© Apple

Antenna/speaker enclosure
This improved audio chamber aids in clarifying sounds leaving the iPhone 4, including calls via speakerphone as well as music played through the speaker inside this housing.

Dock connector
The 30-pin dock connector is the same as on previous iPhone models and positioned as usual at the base of the device.

Long life

The iPhone 4 comes with a built-in rechargeable lithium-ion battery that can be charged by USB or power adaptor. The new bigger battery provides up to seven hours talktime on 3G networks and up to 14 hours on 2G. The standby time is a goliath 300 hours. Internet usage longevity is also up from the iPhone 3Gs and stands at six hours on 3G and ten hours on Wi-Fi. Equally, the iPhone 4 is now capable of a splendid ten hours of video playback and 40 hours of audio playback before needing to be recharged.



Gyroscope

The current iPhone 3GS is not just fitted with a simple accelerometer – a type of sensor that can detect a device's linear acceleration along one of three x, y and z axes – but a combined accelerometer, compass and gyroscope, providing precise information about six-axis movement in space. The iPhone 4, however, adds an additional new electronic sensor for detecting three-axis angular acceleration to its gyroscope around the x, y and z axes, enabling precise calculation of pitch, yaw and roll.

Learn more

For more info and images of the exposed iPhone 4, visit the gadget surgeons at ifixit.com who kindly contributed the photos and findings for this article.

HOW IT WORKS

INVENTIONS

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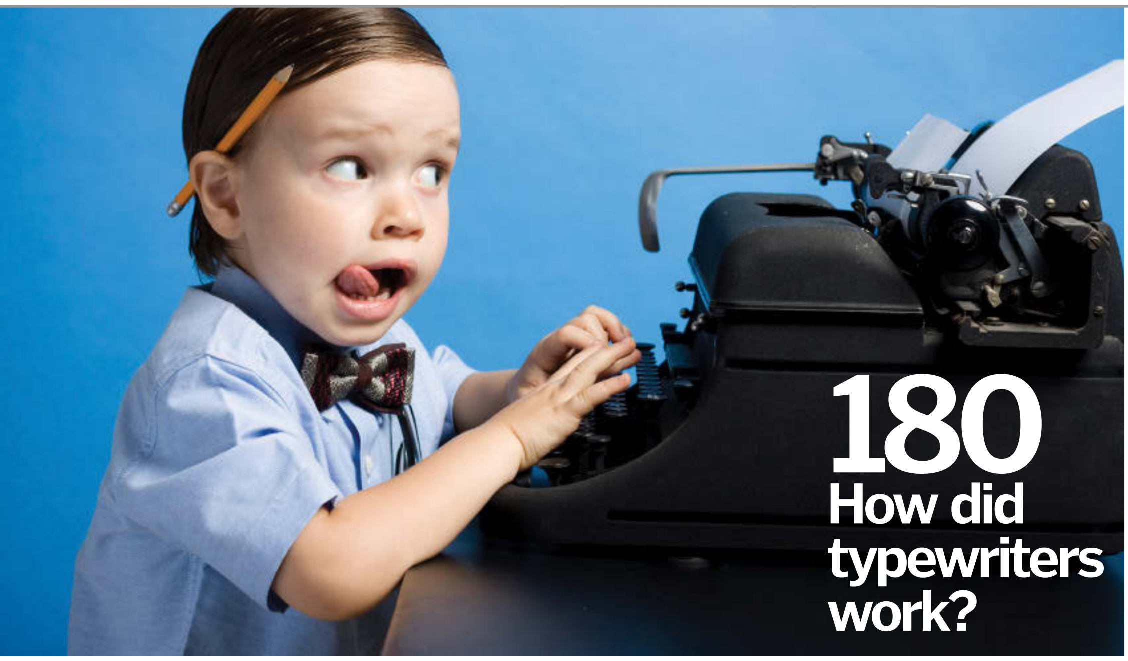
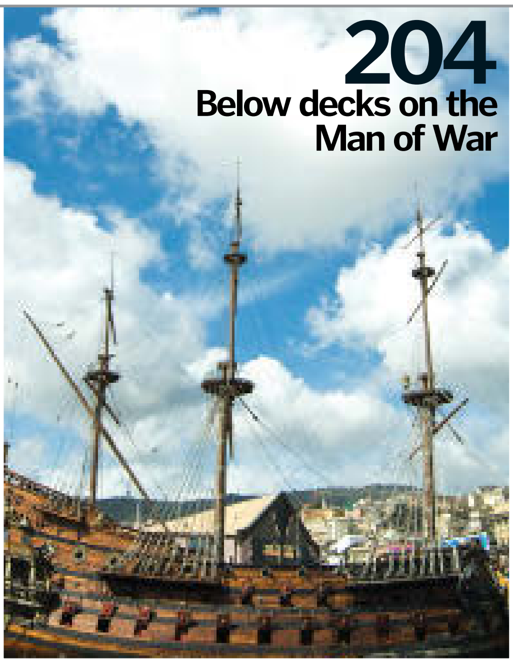


180 How did typewriters work?



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Mark I tank

Created as a solution to trench warfare, the Mark I tank heralded a new era of armed conflict

The world's first ever combat tank, the Mark I has been entrenched in military history and the human consciousness for reasons both good and bad. With its unique rhomboid-shape design, progressive adoption of caterpillar tracks and ability to deliver massive firepower and armour in a mobile unit, it is celebrated as a great technical achievement that broke the domination of trench warfare.

However, it is also remembered as the invention that led many men to die in the most horrendous of manners, both enemy and ally alike, either mown down by its awesome firepower, or entombed in its hot, smoky innards, incinerated when its armour was breached. Technically, for the time its design and mechanics were revolutionary, but they came at the cost of an additional fatal separation between cause and effect – no longer were battles fought between men, they were fought between men and machines.

The Mark I was powered by a Daimler six-cylinder, 13-litre capacity engine. Despite its large size, however, the engine was only capable of producing 105 brake horsepower and despite it being chosen for its reliability, because it was fitted in the same compartment of the tank as the rest of the crew, the fumes, noise and heat it produced made conditions incredibly challenging. The engine was initiated by four members of the crew winding a huge crank handle (similar to those on early fighter planes) and was cooled by water.

As for weapons, the primary, male-variant of the Mark I was mounted with two six-pounder naval guns, one in each sponson (rotatable turret-like structures on its sides), as well as three light machine guns. The lighter female variant of the Mark I was fitted with two heavy Vickers machine guns instead of the six-pounders. The Hotchkiss six-pounder naval guns had a range of 6,860 metres (22,500 feet) and were aimed with basic telescopic sights by their gunners. Each Mark I carried 334 shells.

In terms of defence, the thickness of the Mark I's armour varied over its chassis. In crucial areas such as the front for example, it was 10mm thick, however elsewhere such as the rear, it was only a slight 6mm thick. This meant that while the tank could not be breached by small arms fire and shrapnel, any direct shell or mortar hit would likely breach its resistance threshold. As the First World War progressed, however, the creation of harder, armour-piercing bullets reduced the effectiveness of the armour.

Controlling the Mark I was an epic task, requiring four crew members working in unison. One driver operated the brakes, the other driver meanwhile operated the primary gearbox. Track control was then independently operated by the unit's two gear men. Compounding this was the fact that inside the tank the noise of the engine was deafening, meaning that communication had to be conducted using both sign language and Morse code.

The statistics...

Mark I tank

Crew: 8

Length: 9.8m (32ft)

Width: 4.2m (13.7ft)

Height: 2.4m (8.8ft)

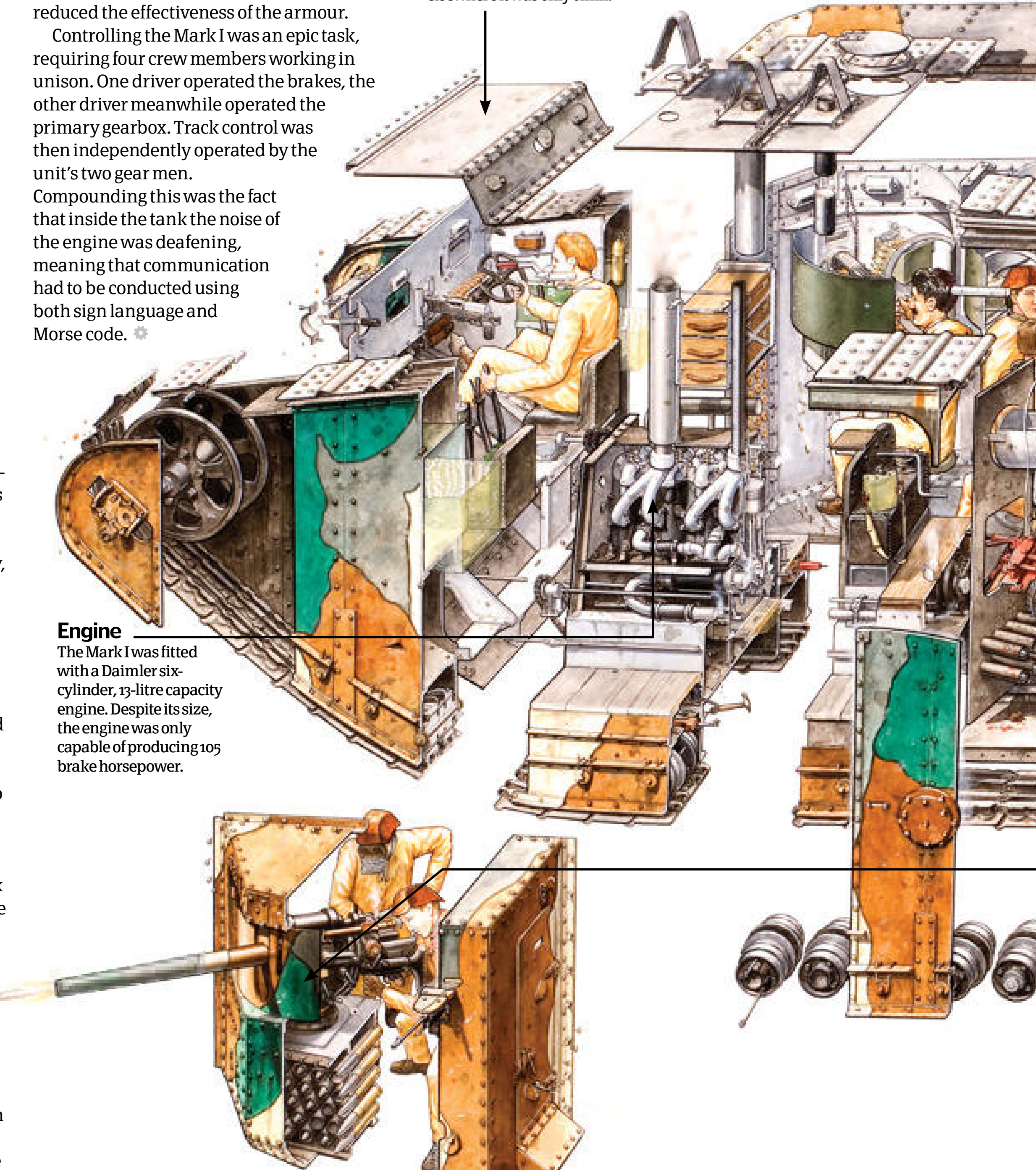
Weight: 28 tons

Armour: 5.8-11.9mm

Fuel capacity: 227.3 litres

Max speed: 6.5km/h (4mph)

Armament: Two six-pounder (57mm) naval guns, four 7.62mm Hotchkiss air-cooled machine guns



Armour
The thickness of the Mark I's armour varied over its chassis. In crucial areas such as the front it was 10mm thick, elsewhere it was only 6mm.

Engine
The Mark I was fitted with a Daimler six-cylinder, 13-litre capacity engine. Despite its size, the engine was only capable of producing 105 brake horsepower.

5 TOP FACTS MARK I TANK

Gender

1 There were two different types of the Mark I. There was the primary, male variant, which was heavier and armed with dual cannons, as well as a lighter female version.

Risky

2 Communication between tanks and command posts relied on carrier pigeons – who had their own small exit hatch in the tank – as well as runners.

Salvage

3 The Mark I was susceptible to mortar fire as its fuel tanks were fitted high up in the cabin. These hits caused crews to be incinerated in the resultant blast.

Tail

4 In order for the Mark I to make slight turns it required the help of a steering tail, a dual-wheel trolley, which, when operated correctly would help turn the tank.

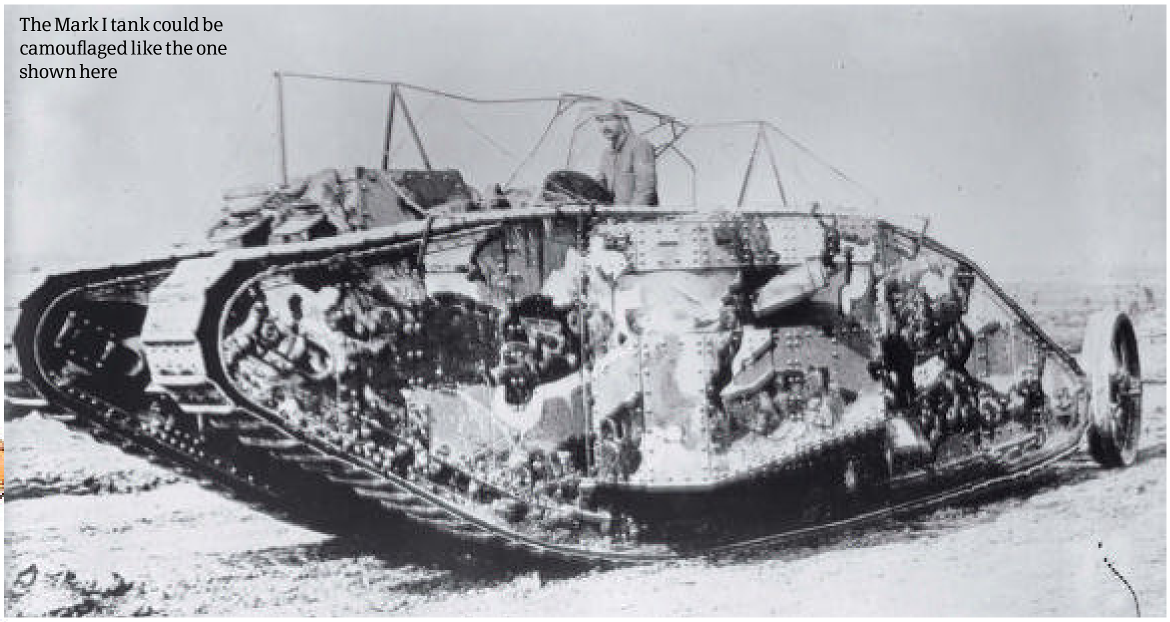
Noxious

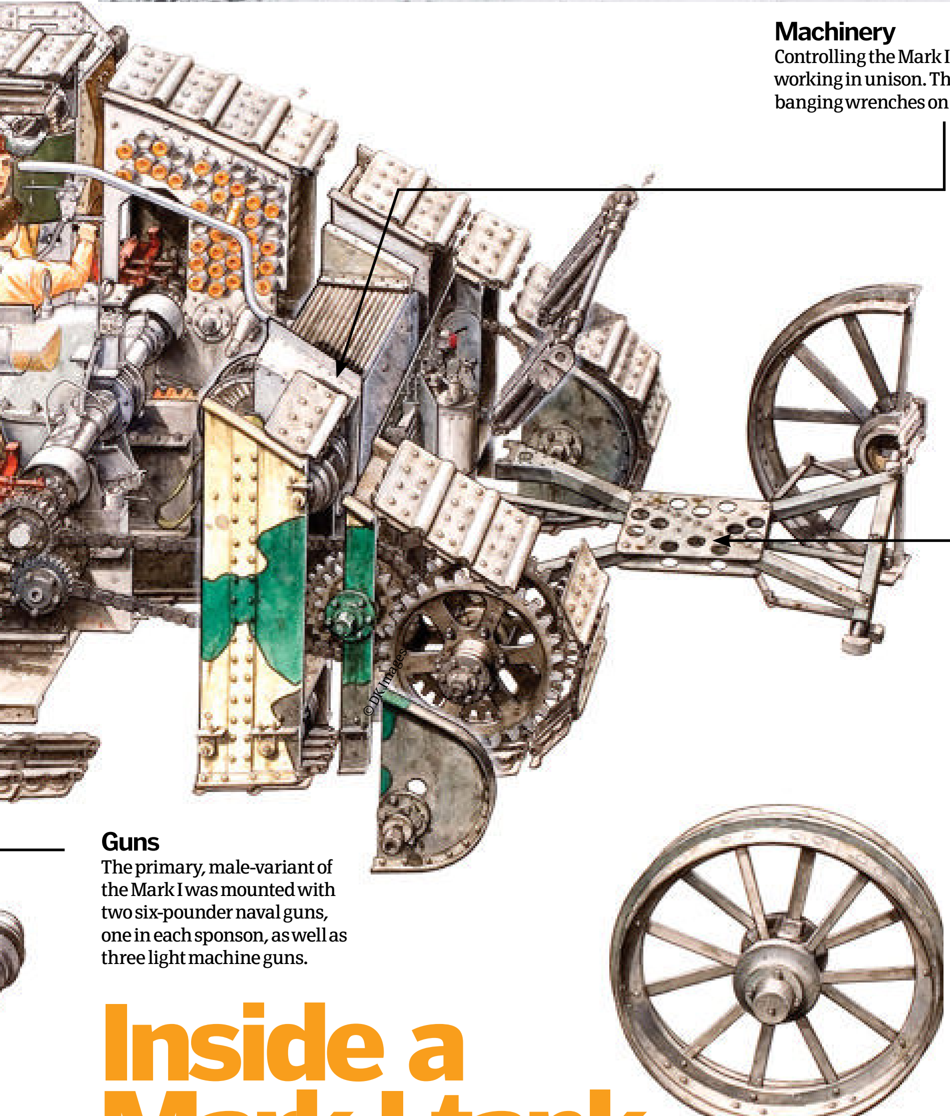
5 The design of the Mark I placed the crew in the same compartment as the engine. Not surprisingly this led to an extremely hot and fume-heavy environment.

DID YOU KNOW? *The prototype of the Mark I was nicknamed 'Mother'*

Inside a Mark I tank

Discover what made it so deadly

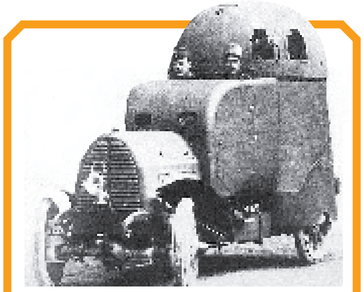

The Mark I tank could be camouflaged like the one shown here


© DK Images

Machinery
Controlling the Mark I required four men working in unison. They communicated by banging wrenches on the tank's chassis.

Tail
The Mark I was initially fitted when released with a steering tail trailer that helped the tank make slight turns. It worked akin to the rudder mechanism of a boat, with each wheel capable of being locked by the driver.

Guns
The primary, male-variant of the Mark I was mounted with two six-pounder naval guns, one in each sponson, as well as three light machine guns.



Automotive armour

The concept of an armoured vehicle had been around long before the Mark I

With the advent of the motor car in the later 19th Century, during the first decade of the 20th, numerous self-propelled armoured fighting vehicles were designed and built in America and Europe. These vehicles tended to be modified motorcars, with armoured panels replacing standard chassis components and light machine guns mounted at the front and rears.

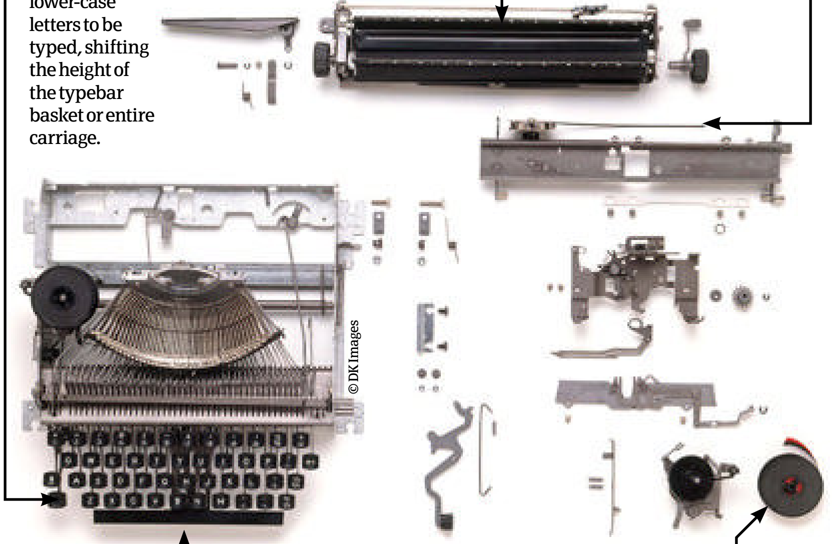
Although these vehicles were relatively effective on level terrain in cities and on roads – allowing decent firepower to be transported quickly over long distances – their use was rendered moot on the battlefield due to the muddy, inconsistent ground surface. Further, due to their light frame they were easily destroyed with grenades and shells.

A Mark I in operation at the Somme, France, on 25 September 1916

Typewriters

Mechanical devices used to type text onto paper, typewriters paved the way for modern word processors

The new issue of How It Works is under way!


© DK Images

Shift key
The shift key allowed both upper- and lower-case letters to be typed, shifting the height of the typebar basket or entire carriage.

Platen
The typewriter's cylindrical roller moved back and forth. The platen friction-fed paper into position.

Carriage return
The carriage return lever rotated the platen so the paper would drop onto the next line.

Typebar
Each key of the typewriter was attached in reverse to a typebar. The bars were guided up to the inked ribbon through a segment.

Ribbon
The inked fabric ribbon was stretched in front of the cylindrical platen and provided the ink for the key strike impressions.

Mechanical typewriters work by imprinting inked key heads – containing one or more letters, numbers or symbols – onto a sheet of paper one after the other to form lines of text. To achieve this, five vital standardised parts are implemented into each typewriter's body.

At the bottom-centre of the unit a mechanical keyboard is connected to a basket of typebars. Qwerty keyboard layouts are common, although other layouts have also been used. When their corresponding key is raised, it's guided by a segment channel vertically up to the unit's ribbon. The ribbon is a strip of fabric that was covered with the type's ink. When struck by the head of the typebar – onto which letters, numbers and symbols have been affixed – the corresponding letter is then printed onto the sheet of paper.

The typewriter's paper is held in place around a cylindrical tube referred to as a platen, which itself can move from left to right horizontally within a carriage system. The platen can be incrementally wound at the end of each line of text with the carriage return. The carriage return is a lever positioned at the end of the carriage, which drops the paper onto the next line for continued text.

Finally, the basket of typebars can be shifted up and down with the shift key, allowing its user to move between lower case and upper case type. Raising the typebar up to the ribbon in a new position means a different part of the typebar's head can now strike the ribbon, imprinting a different letter, number or symbol.

Meet Madame Guillotine

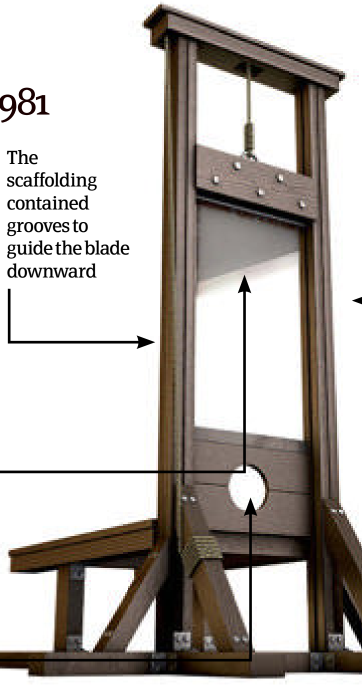
The guillotine was the official method of execution in France until 1981

During the French Revolution, anatomy professor Joseph-Ignace Guillotin proposed that capital punishment in France should be carried out by decapitation on people of all classes because it was the most humane method available. Dr Antoine Louis of the Academy of Surgery designed the machine that came to be known as the guillotine after pointing out that beheading by sword was highly impractical.

The guillotine consists of a wooden frame with an angled blade that runs along grooves. After the executioner raises the weighed blade with a rope, the condemned is placed on a platform with his or her head in a round wooden frame called a lunette. The executioner lets go of the rope, allowing the blade to drop. Until abolishment of the death penalty in 1981, France continued to use the guillotine as its method of execution. Although still legal in a few other countries, the guillotine has not been used since.

> "Beheading by sword was impractical"

DID YOU KNOW?
Numerous witnesses have reported heads moving, speaking and blinking for a few seconds after decapitation.


Some blades were raised by means of a crank on the side of the scaffolding

The scaffolding contained grooves to guide the blade downward

Some executioners had a casket nearby to catch the head as it fell

Blades could be curved or flat, but angled blades worked best

The condemned's head was immobilised by a lunette

The Wright Flyer

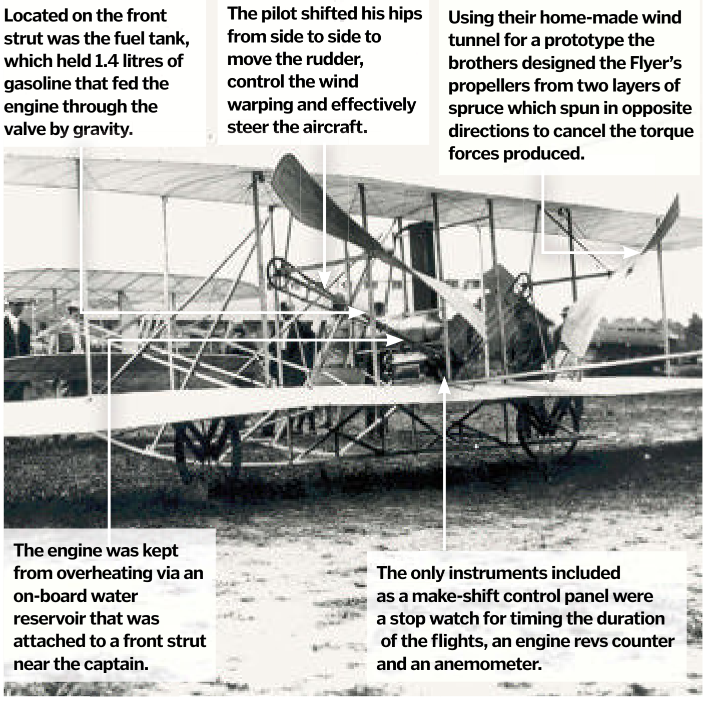
The Wright brothers' first powered plane was called the Wright Flyer, find out how it worked

On 17 December 1903 in Kitty Hawk, North Carolina, the Wright Brothers – Orville and Wilbur – alternately flew their 'Flyer' four times, the longest of which covered 259 metres (852 feet) lasting just a second short of a minute. These daring feats on that fateful day meant they became the first people to successfully invent, build and pilot a heavier-than-air power-driven machine.

The main breakthrough of the Flyer is cited as the aviators' invention of three-axis control, which enabled the pilot to steer effectively and maintain its equilibrium. The direction of the plane was controlled using a unique hip cradle invention which was operated by the pilot sliding his hips from side to side and lean into the turn. This was connected to the plane's wingtips with wires, forcing the wings to twist, and by extension – roll. To assist these turns, the American inventors pioneered the idea of wing warping – the twisting of the wing – resulting in one end of the wing having more lift than the other. A rudder was also connected and controlled by the cradle.

The plane could be pulled up and down by a pull system which was operated by the pilot's left hand. Today the elevator is traditionally located in the tail section, but in 1903 the Wrights decided to place it in the front of the plane as they assumed it would prevent the plane from nose-diving if the plane stalled. The aircraft was powdered by a 12 horsepower four-cylinder gas engine, constructed with the help of machinist Charlie Taylor and weighed 77kg. The solitary control bestowed upon the engine was a fuel valve that was connected to a stick and once the engine was active this valve was used to cut the power.

To this day both states of Ohio and North Carolina take credit for the Wright brothers and their extraordinary inventions. Ohio because Dayton was the base for the pair's development and construction of their designs and North Carolina because Kitty Hawk was the site of this first world-changing flight. ⚙



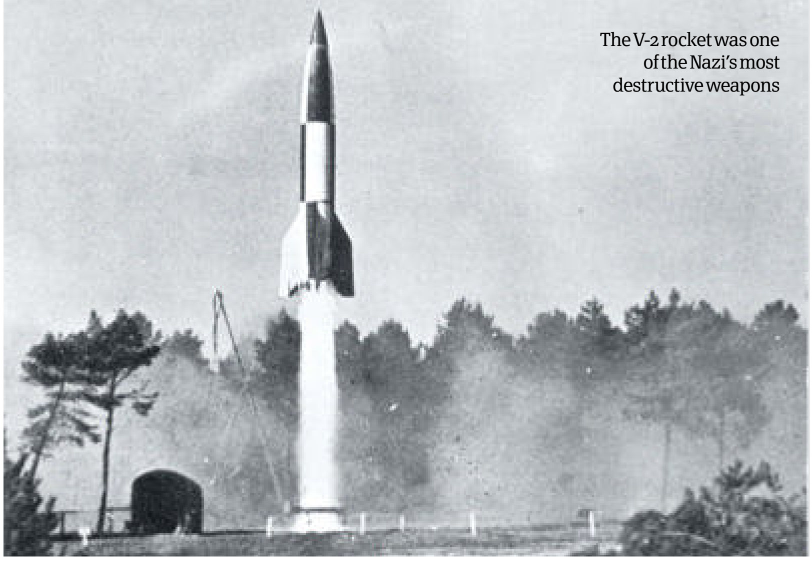
Located on the front strut was the fuel tank, which held 1.4 litres of gasoline that fed the engine through the valve by gravity.

The pilot shifted his hips from side to side to move the rudder, control the wind warping and effectively steer the aircraft.

Using their home-made wind tunnel for a prototype the brothers designed the Flyer's propellers from two layers of spruce which spun in opposite directions to cancel the torque forces produced.

The engine was kept from overheating via an on-board water reservoir that was attached to a front strut near the captain.

The only instruments included as a make-shift control panel were a stop watch for timing the duration of the flights, an engine revs counter and an anemometer.



The V-2 rocket was one of the Nazi's most destructive weapons

V-2 rocket

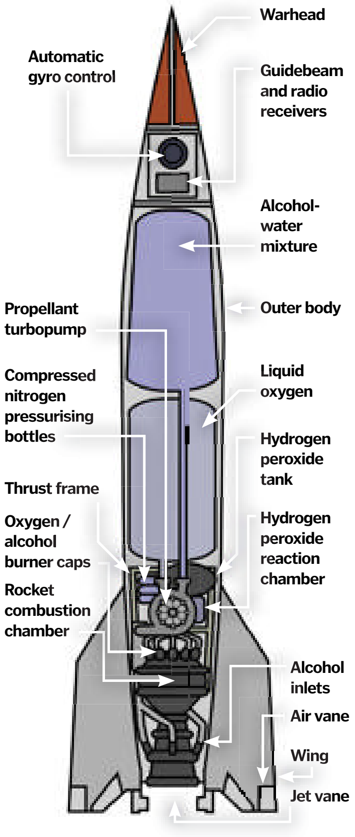
How Hitler's V-2 rocket worked and why it could have won the war

The V-2 – short for Vergeltungswaffe-2 and also known as the A-4 – was the world's first ballistic missile. It was created by the Nazi military during WWII and inspired many generations of replicas still in production today.

The V-2 rocket was designed for sub-orbital space flight, therefore launched from Earth until it reached an altitude of 80km and fell back down to Earth, exploding upon impact. The V-2 programme was supposedly the single most expensive development project of the Third Reich. It claimed the lives of 20,000 inmates of the labour camp Mittelbau-Dora, who died constructing over 6,000 replicas of the device. It's thought to be the only weapon system of its kind to have caused more deaths during production than usage.

The first successful launch was in October 1942 but it wasn't fully employed in the war effort until September 1944 where it was used to bomb Paris and London. London received the second highest number of attacks (Antwerp being the most common target) killing 2,752 civilians – two people per V-2.

While in the beginning many were misdirected and exploded harmlessly, improved accuracy during its development resulted in missiles claiming hundreds of lives at a time. Anti-aircraft and gunfire were no match for the V-2's speed and trajectory, dropping at four times the speed of sound. It's thought that if the deployment of the V-2 happened a few years earlier, Hitler could have won the war.

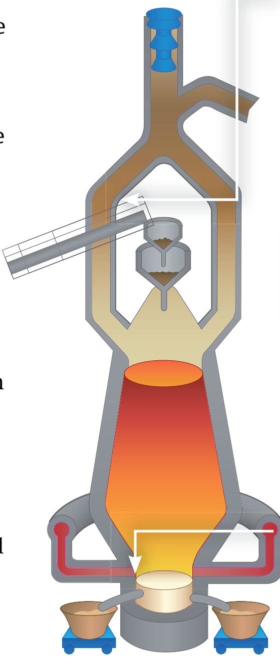


The blast furnace

An enclosed chamber that uses high temperatures to produce iron and steel

The blast furnace was a major catalyst for the Industrial Revolution as the smelting of iron kick-started the iron trade. Iron ore, coke and limestone are fed into the top of the furnace at a regular rate. As this moves down through the furnace it is blasted by hot air (up to 1,200°C). The coke burns in the hot air and acts as a fuel to melt the iron ore while the limestone causes the rocky material in the iron ore to become molten slag.

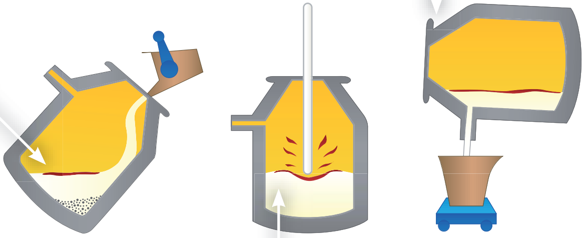
The molten slag floats on the molten iron at the base of the furnace. Separate clay taps are broken to pour off the molten slag and iron. The molten iron is usually sent to be made into steel before it cools off to form pig iron. Slag is dumped and used for road building. Blast furnaces can run for several years before their brick refractory linings need replacing.



1. Blast furnace
The iron ore, coke and limestone is dropped into the top of the furnace through bell shaped hoppers.

2. Molten iron
Hot air is blasted into the furnace. The high temperature causes the iron and impurities (slag) to melt and separate. They are 'tapped' off into separate ladles.

Making steel



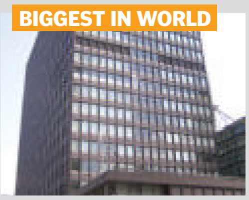
3. Oxygen converter
The resulting pig iron still contains many impurities. To become steel it is poured into a converter furnace and mixed with scrap iron.

4. Gas
A water-cooled lance blasts oxygen into the iron. This process releases carbon from the iron in the form of carbon monoxide gas.

5. Steel
The converter is rotated on its axis to pour the molten steel into a railway ladle. The steel can now be cast into ingots or rolled into billets.

Head to Head
INDUSTRIAL FURNACE

BIGGEST IN WORLD



1. Nippon Steel, Oita Works, Japan
The No 2 furnace at this steelworks has a working volume of $5,775m^3$. When restarted in 2010, it suffered problems.

BIGGEST IN WEST

© ThyssenKrupp

2. ThyssenKrupp Steel, Duisburg-Schwelgern
The No 2 furnace in Germany has a capacity of 5,513 cubic metres. It can produce 10,000 tons of molten iron a day.

BIGGEST IN INDIA

© JSW Steel

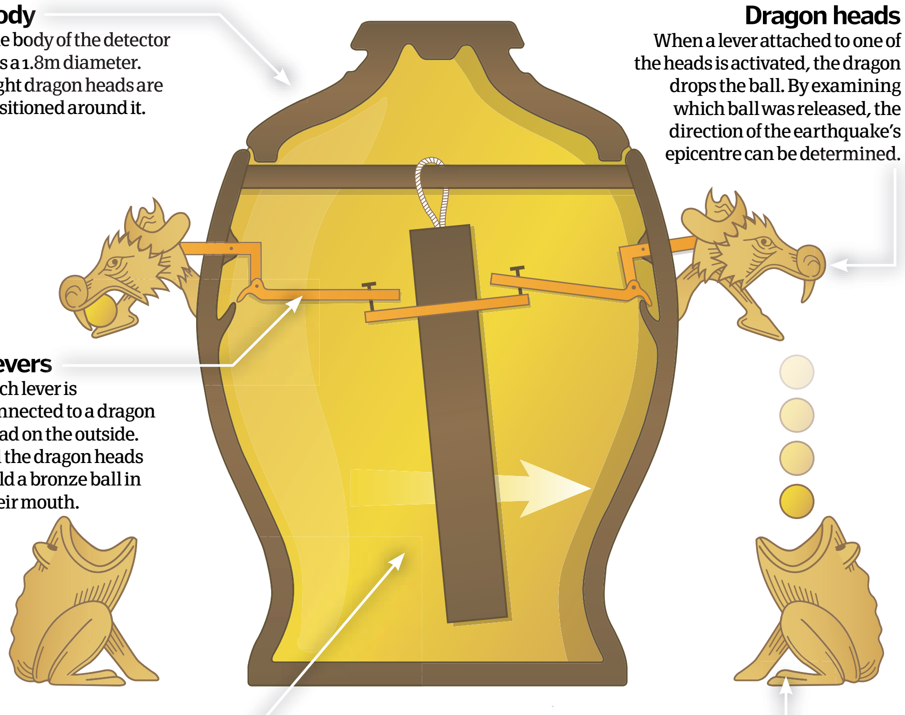
3. JSW steelworks, Vijayanagar
Commissioned in 2009, the No 3 furnace has a capacity of 4,019 cubic metres.

Chinese earthquake detector

The world's first instrument for measuring the seasonal winds and the movements of the Earth

Now, this might look like a huge ornamental vase, but in reality, it is an earthquake detector invented by the Chinese philosopher and astronomer Zhang Heng in AD 132, during the Eastern Han Dynasty. The 'Houfeng didong yi' as it was called, is described in the 5th Century 'History of the Later Han Dynasty', but an actual working version of it has not survived. This has led to much speculation about the details of how the pendulum mechanism worked inside the detector.

Zhang Heng built the device on the principle that when winds are compressed into narrow spaces with no means of escape, they cause any obstacles to be dislodged and tossed "with a deep murmur." His device was claimed to be so sensitive it detected an earthquake 650 kilometres (400 miles) away, which was confirmed when a rider was dispatched to the area.



Body
The body of the detector has a 1.8m diameter. Eight dragon heads are positioned around it.

Dragon heads
When a lever attached to one of the heads is activated, the dragon drops the ball. By examining which ball was released, the direction of the earthquake's epicentre can be determined.

Levers
Each lever is connected to a dragon head on the outside. All the dragon heads hold a bronze ball in their mouth.

Pendulum
The pendulum responds to earth tremors, which causes it to swing in the opposite direction to the tremor's epicentre. This movement triggers one of the levers surrounding the pendulum.

Toads
Eight toads are positioned underneath each dragon head. They catch the balls dropped by the dragon heads. When a toad catches a ball, it makes a sound to warn of the earthquake.

5 TOP FACTS
BEARD FACTS

Growing

1 The average human male grows 25,000 hairs on his face in the space of 24 hours. They will grow about half a millimetre in a day and 13 millimetres in a month.

Genetic

2 Genetic factors determine the length, texture, colour and growth patterns of facial hair. Another factor that plays a part in hair growth is hormones.

Tug of war

3 Legendary King Alexander the Great ordered his soldiers to shave, as he feared that in battle the enemy could easily grab their beards and kill them.

Plucking

4 The great Roman ruler Julius Caesar had his facial hairs pulled out one by one by tweezers, rather than trust anyone to use a razor on his throat.

Wet and dry

5 When put under a microscope and examined, a wet razor shave looks much smoother than a dry shave carried out by an electric shaver.

DID YOU KNOW? *Gillette safety razors were given to US soldiers in WWI so that gas masks would fit their clean-shaven faces*

The first safety razor

Developing a safe and close shave

Jean-Jacques Perret is regarded as the inventor of the first safe razor that would not accidentally cause serious injury to your face. From about 1600 until the 1900s, when the disposable safety razor was introduced, the most common shaving implement was the straight razor. It was capable of cutting a man's throat and was easily employed as a murder weapon or means of committing suicide. Not surprisingly, it was commonly called a 'cut throat' razor.

The straight razor consists of a blade that pivots on a pin attached to the top of a handle. This allows the blade to be folded – edge first – into the handle when it is not being used. It needed to be regularly sharpened and required a skilled hand to use it properly. For those reasons, the local barber was the main place where men went for a shave, as barbers were specially trained to use a straight razor.

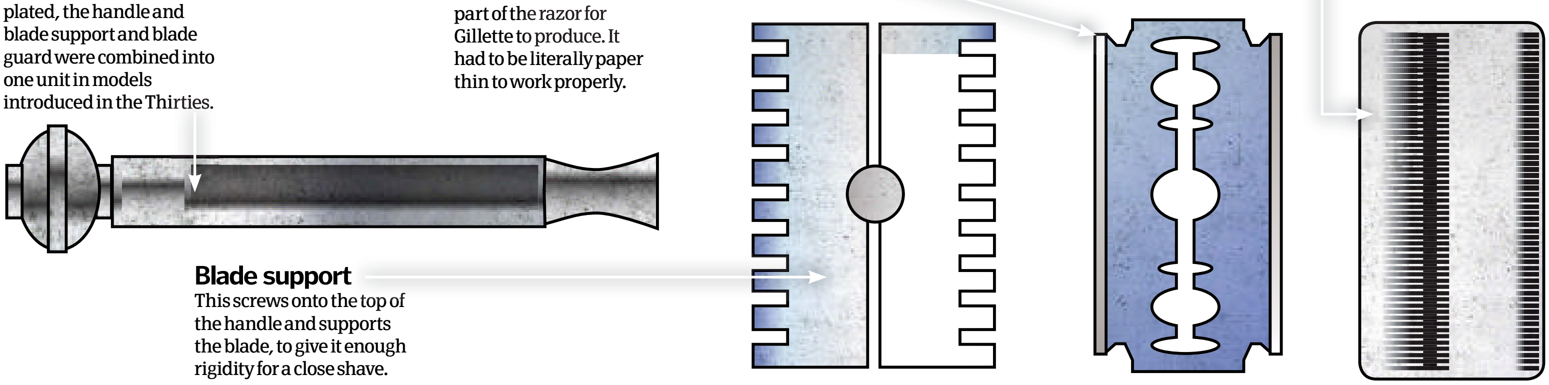
Jean-Jacques Perret was a master cutler who had a detailed knowledge of the science of steel making. Based in Paris, in 1769 he published a treatise called 'Pogonotomie, or The Art of Shaving Oneself' (Pogonotomie, au L'Art D'Apprende à se Raser Sol-Méme). This includes a description of a rasoir à rabot (razor with plane) that he invented in 1762 after seeing a carpenter's plane in action. Perret's idea was to sheath the blade of a straight razor with an L-shaped wooden sleeve, so that only the cutting edge of the blade was visible. This made it easier for more people to safely shave, and many European manufacturers subsequently copied his idea.

The disposable shave: Gillette's razors became a household name

Gillette's disposable blade

King Camp Gillette was an American travelling salesman who found it time-consuming to sharpen his cut-throat razor on a leather strop. He thought it was wasteful to have a large and dangerous blade, when you could make a safe one to suit the size of a man's face. Alongside engineer William Emery Nickerson, Gillette produced a double-sided razor blade that fitted in a holder mounted on a handle. The blades were made of ultra-thin carbon steel and Gillette guaranteed they could be used for 20 shaves. Their cheapness and disposability meant that stropping was a thing of the past, and Gillette knew that he would make a fortune from selling the replacement packs of blades. His razor was patented in 1901 and went on sale in 1904.

Parts of the safety razor



Handle
Originally silver- or gold-plated, the handle and blade support and blade guard were combined into one unit in models introduced in the Thirties.

Blade
This was the hardest part of the razor for Gillette to produce. It had to be literally paper thin to work properly.

Blade guard
This is placed on top of the blade and, along with the blade support, clamps the blade in position.

Blade support
This screws onto the top of the handle and supports the blade, to give it enough rigidity for a close shave.

Evolution of the close shave

Prehistoric period

Prehistoric man used sharpened flint stones and even sharks' teeth to shave his hair. He also used two seashells as tweezers to pull out facial hair.

Ancient Egypt

In the Early Dynastic Period (3150 -2686BC) ancient Egyptians used sharpened stones on handles for shaving. Later, bronze and copper razors were used by barbers to shave military men, the aristocracy and the public.

Cast steel

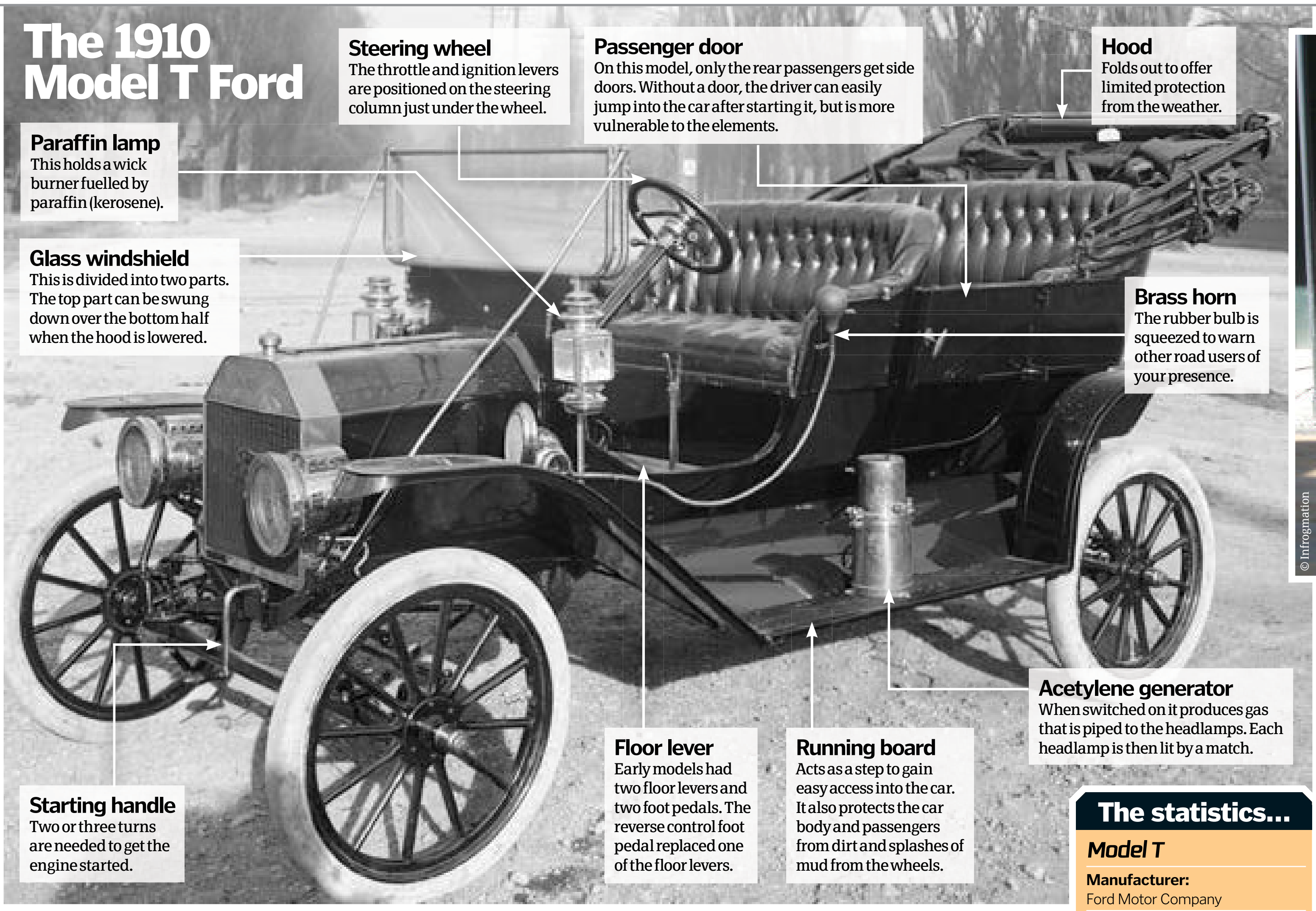
The straight razor was a development from earlier razors – it improved when constructed with crucible or cast steel. Benjamin Huntsman invented this steel in Sheffield in 1740.

Disposable razors

Since 1904, disposable razors have dominated the market. In 1974, the completely disposable plastic razor was introduced. Now, disposable razors or those with disposable shaver heads containing two or more blades are the norm.

The electric shaver

Jacob Schick patented a handheld electric shaver in 1923. With the development of smaller and more powerful electric motors in the late-Thirties, they found a growing market.



The 1910 Model T Ford

Steering wheel
The throttle and ignition levers are positioned on the steering column just under the wheel.

Passenger door
On this model, only the rear passengers get side doors. Without a door, the driver can easily jump into the car after starting it, but is more vulnerable to the elements.

Hood
Folds out to offer limited protection from the weather.

Paraffin lamp
This holds a wick burner fuelled by paraffin (kerosene).

Glass windshield
This is divided into two parts. The top part can be swung down over the bottom half when the hood is lowered.

Brass horn
The rubber bulb is squeezed to warn other road users of your presence.

Acetylene generator
When switched on it produces gas that is piped to the headlamps. Each headlamp is then lit by a match.

Starting handle
Two or three turns are needed to get the engine started.

Floor lever
Early models had two floor levers and two foot pedals. The reverse control foot pedal replaced one of the floor levers.

Running board
Acts as a step to gain easy access into the car. It also protects the car body and passengers from dirt and splashes of mud from the wheels.

© Infrognation

The Model T

The car that brought motoring to the masses

The statistics...

Model T

Manufacturer: Ford Motor Company

Year introduced: 1908

Dimensions: Length: 2,540mm, width: 1,422mm, height: 2,387mm

Engine: 2896cc

Top speed: 45mph

Horse power: 22.5

Required fuel: Petrol

Unit price: $850

Early Model T styles included this popular open-top touring car

By today's standards, Henry Ford's Model T has many unusual characteristics. Before you can jump into the driver's seat, you have to turn a hand crank at the front of the car to start it. This is a hazardous process as the hand crank can break your thumb if the engine backfires, and if the throttle lever on the steering column is not set properly it will run you over as soon as it starts. Fortunately, an optional electric starter was introduced in 1919.

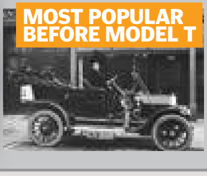
The Model T has three foot pedals and a floor lever. To drive off, you increase the throttle lever, move the floor lever forwards from its neutral position and depress the clutch foot pedal on the left. As you pick up speed, you can move from first to second gear by releasing pressure on the clutch pedal. To stop, simply reduce the throttle, press down the clutch pedal, depress the brake foot pedal on the right and put the floor lever into neutral. To go backwards you keep the floor lever in neutral and press down the middle reverse foot pedal.

Early versions of the car had brass acetylene lamps, and its ten-gallon fuel tank was mounted under the front seat. As this fed petrol to the carburettor using gravity, the Model T could not climb steep hills if the tank was low on fuel. The solution to this was to drive up hill in reverse.

Its engine is front mounted, and features four cylinders in one en bloc

Head to Head
EARLY AUTOMOBILES

MOST POPULAR BEFORE MODEL T



1. Buick Model 10
In 1908, 4,002 of these three-seater, Touring Runabouts were sold at a cost of $900 each. The hood was an optional extra. They can now sell for around $40,000.

STEAM CARS

2. White Type E
Before the domination of the Model T and the internal combustion engine, the White Sewing Machine company produced a series of luxury, steam-powered touring cars.

MASS PRODUCED

© Douglas Wilkinson 2006

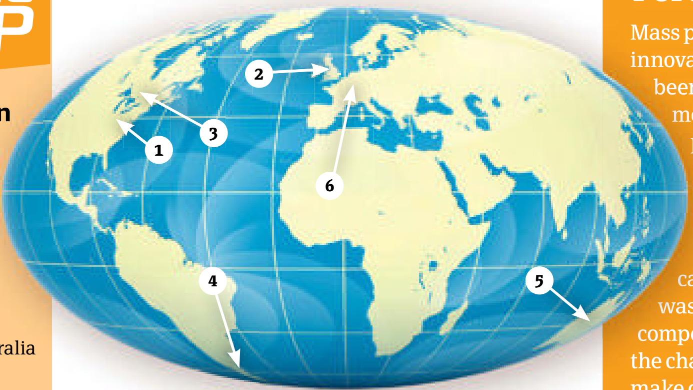
3. Curved Dash Oldsmobile
425 of these vehicles were built using mass production methods in 1901, long before Ford improved these methods. It cost $650.

DID YOU KNOW? *Henry Ford said you can have any colour Model T as long as it is black*

Just as its modern counterparts developed different styles and shapes over the years, so too did the Model T

ON THE MAP

Model T production centres
1 Highland Park Plant, Michigan
2 Trafford Park, Manchester, UK
3 Walkerville, Ontario, Canada
4 La Boca, Buenos Aires, Argentina
5 Geelong, Victoria, Australia
6 Berlin, Germany

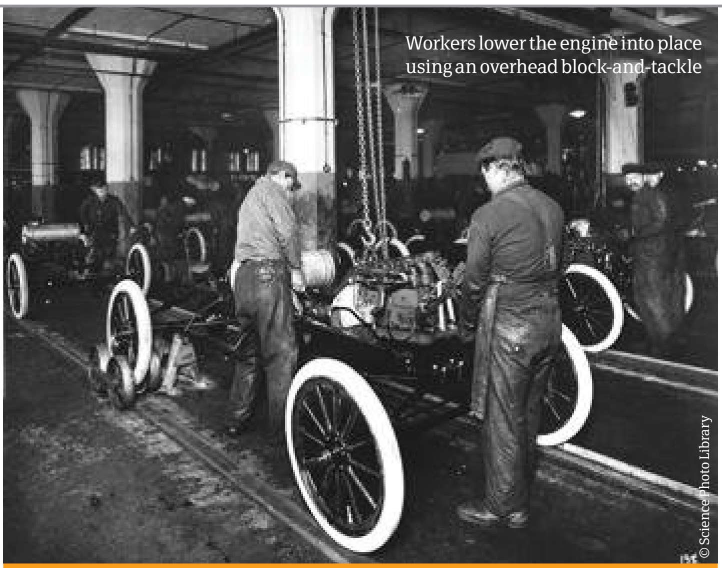


POLICE PRECINCT Nº5
CITY
LIGHT

The Model T was a welcome addition to police forces

© Harry L Sneider

casting. This simple engine is relatively easy to run and maintain. The first models were runabouts with open bodies and a hood that can be folded down. Lots of different car and truck bodies were later fitted to the Model T chassis by Ford and other companies. Since the Model T Ford was equally at home in town or as an off-road farm workhorse, and available at the cheapest price possible, it quickly dominated the USA and made motoring an essential part of our lives.



Workers lower the engine into place using an overhead block-and-tackle

© Science Photo Library

Mass production

The revolutionary methods used by Ford opened up a world of possibilities

Mass production using a moving assembly line was the key innovation that made the Model T so successful. Car production had been largely pitched at the luxury market with hand-built bespoke models being the norm. Henry Leland, who worked for Cadillac, pioneered the standardisation of car components, and moving production lines were used in Chicago slaughterhouses. The genius of Ford was to integrate these methods and reduce the production of the Model T to 84 key areas.

The chassis of the car was run along a track and each worker carried out a very simple and repetitive production task, before it was moved on to the next work area. The engine and other components were made in a similar manner before being added to the chassis. This slavish process made it possible to reduce the time to make one Model T from 12 hours eight minutes to 93 minutes.

As early as 1914, Ford's mass production techniques produced 300,000 cars with 13,000 workers compared to the 66,350 workers at all the other car companies who only produced 280,000 cars.

From 27 September 1908 till the end of production on 26 May 1927, 15 million Model Ts were made. The Model T met and exceeded Henry Ford's vision of creating a simply designed car using the best materials at a price affordable to everyone.

Connecting the barrel-shaped petrol tank

© Science Photo Library

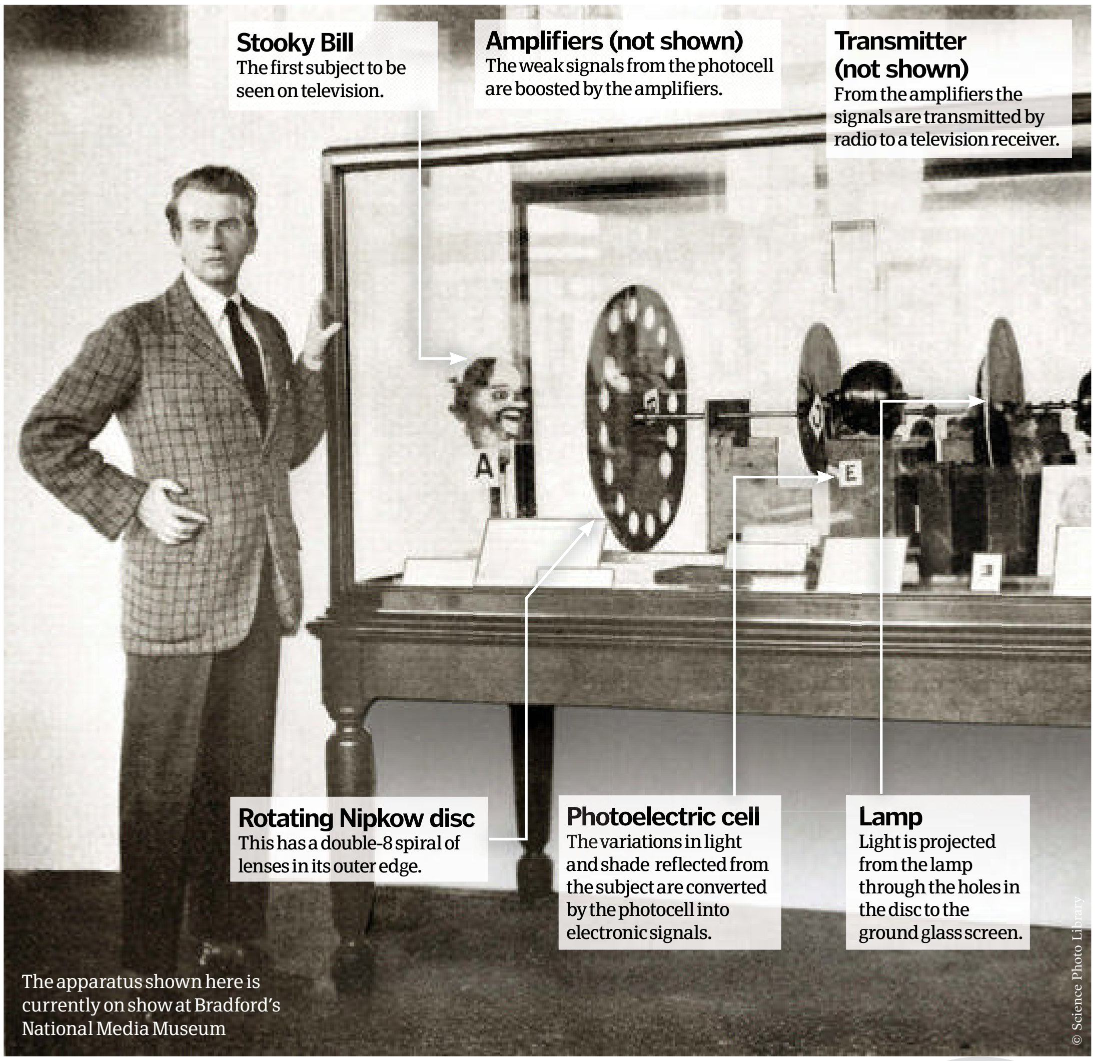
The first television

The start of the 'goggle box' invasion into our homes and minds

Scottish engineer John Logie Baird's breakthrough came on 2 October 1925 when he transmitted a greyscale image of the head of a ventriloquist's dummy called 'Stooky Bill'. Baird immediately replaced Bill with William Taynton who became the first person to appear on TV.

Elements of Baird's system used technology that had been developed during the 19th Century. It employs circular Nipkow discs to obtain 32 lines of vertically scanned images at a rate of five pictures per second. Baird's disc had a double-8 spiral of 16 lenses on the outer edge that orresponds to the 32 lines of the full television picture. Two rotations of the disc produce one complete television picture frame.

The light from the scanned subject is converted by a selenium photocell into electronic signals that are sent by radio waves to a receiver. Here, the signals trigger a neon tube to flash behind a spinning disc with holes on its edge. The light from the disc reproduces the transmitted pictures onto a ground glass screen. ⚙



Stooky Bill
The first subject to be seen on television.

Amplifiers (not shown)
The weak signals from the photocell are boosted by the amplifiers.

Transmitter (not shown)
From the amplifiers the signals are transmitted by radio to a television receiver.

Rotating Nipkow disc
This has a double-8 spiral of lenses in its outer edge.

Photoelectric cell
The variations in light and shade reflected from the subject are converted by the photocell into electronic signals.

Lamp
Light is projected from the lamp through the holes in the disc to the ground glass screen.

The apparatus shown here is currently on show at Bradford's National Media Museum

© Science Photo Library

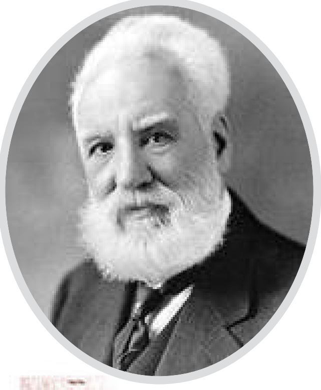
The first telephone

The telephone was a worldwide revolution and the start of instant long-distance communication

The first telephones to be manufactured featured three main parts: a speaker, a microphone and a hook switch, but the first telephone was much more basic.

Alexander Graham Bell, who is credited with the first patent for the telephone, created an instrument that featured a transmitter formed of a double electromagnet in front of which sat a membrane stretched around a ring holding a piece of iron in its middle. The mouthpiece was positioned before the diaphragm and when sounds were directed upon it, it vibrated and the iron moved.

This movement induced currents in the coils of the magnet which were passed along the electric current of the line to the receiver which consisted of a tubular electromagnet. One end of this was partially closed by a thin circular disk of soft iron and as the current was received the disk vibrated and acoustic sounds were emitted. ⚙

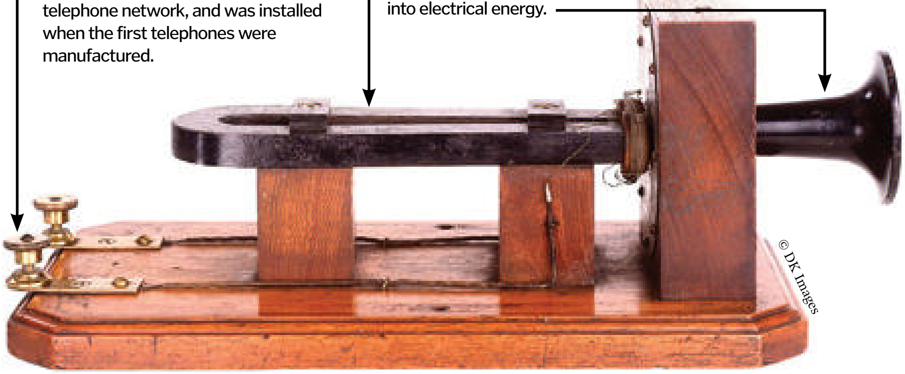


Alexander Graham Bell, the father of the telephone

2. Receiver
The electric charges are pulsed through the line and then converted back into acoustic energy at the other end.

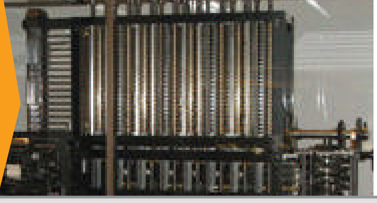
1. Mouthpiece
When a person spoke into the mouthpiece the acoustic vibrations shook the iron held within a stretched membrane in the transmitter which resulted in a variation of voltage, therefore converting acoustic energy into electrical energy.

3. Hook
A hook switch was later added to the device as was used to connect and disconnect the phone from the telephone network, and was installed when the first telephones were manufactured.



© DK Images

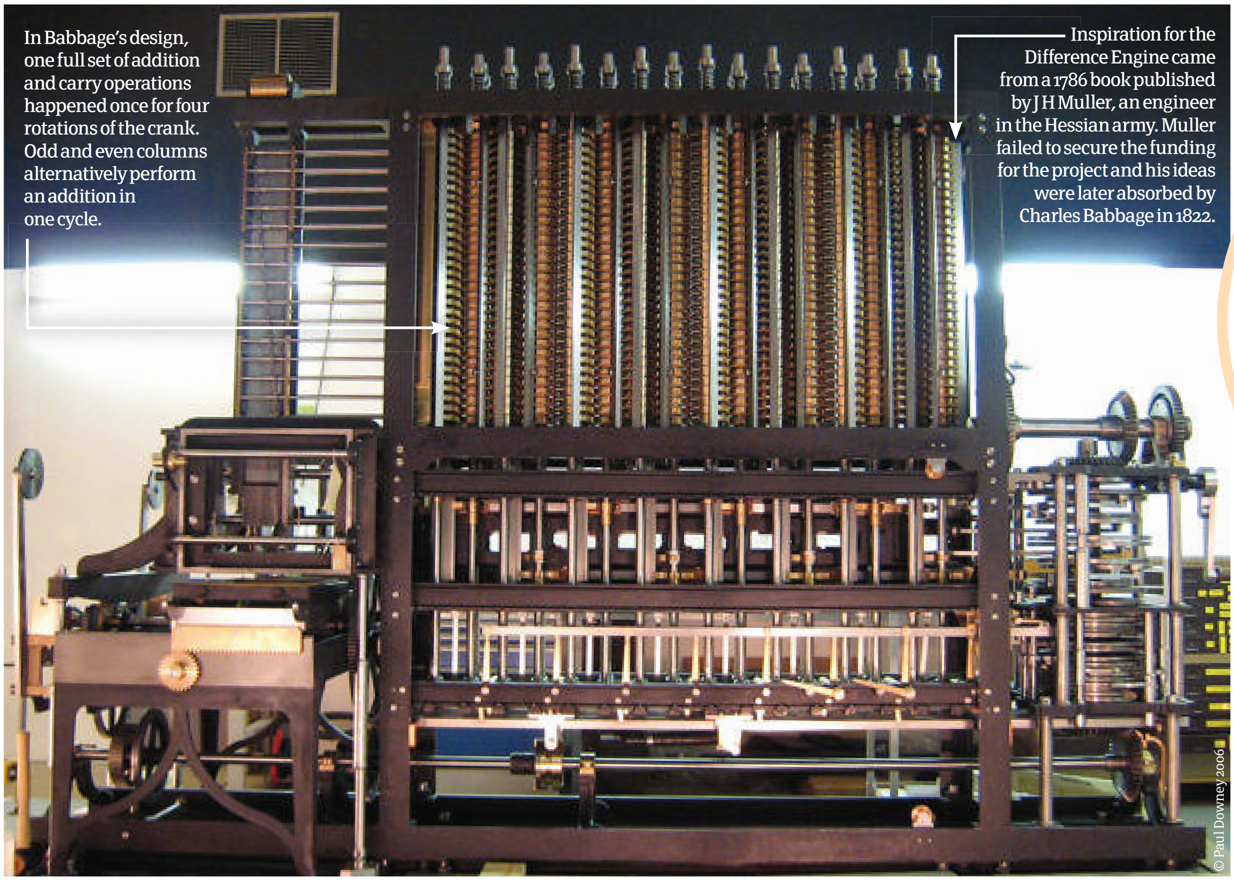
DID YOU KNOW?



The first printer…

The London Science Museum completed Babbage's designs for the Difference Engine No 2 in 1991. In 2000 the engineers constructed and added the printer that was invented to work in tandem with the machine.

DID YOU KNOW? *Babbage stood as a candidate for Parliament for the borough of Finsbury twice*



In Babbage's design, one full set of addition and carry operations happened once for four rotations of the crank. Odd and even columns alternatively perform an addition in one cycle.

Inspiration for the Difference Engine came from a 1786 book published by J H Muller, an engineer in the Hessian army. Muller failed to secure the funding for the project and his ideas were later absorbed by Charles Babbage in 1822.

© Paul Downey 2006

The first computer

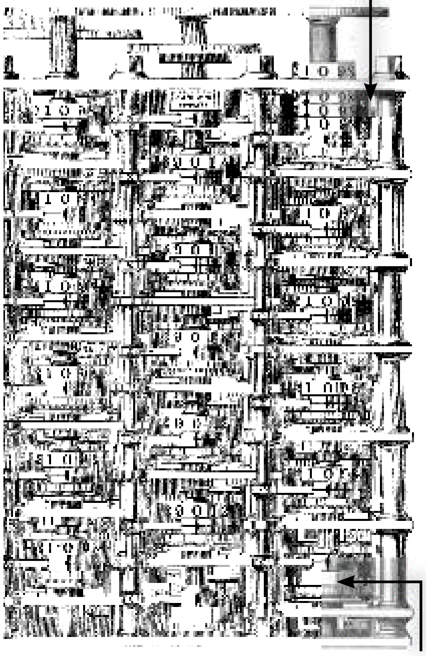
Charles Babbage invented the first computer, called the Difference Engine. How on earth did it work?

The Difference Engine is the first automatic, mechanical calculator designed by British mathematician Charles Babbage, who proposed its construction in 1822 to the Royal Astronomical Society. He suggested the machine would employ the decimal number system and would be powered by turning a handle, as a method to calculate mathematical tables mechanically, therefore removing the high rate of human error.

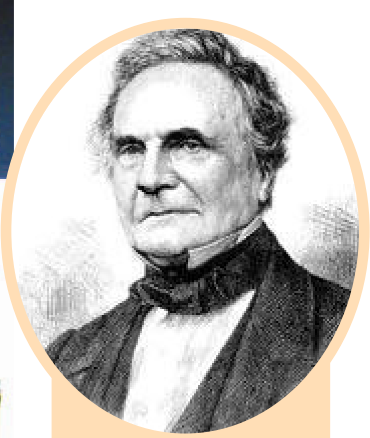
At first Babbage received financial backing from the British Government, but this was later pulled when no apparent progress had been made on constructing the device. The inventor went on to design a more general analytical engine and then later in 1847 an improved engine design – the Difference Engine No. 2.

From 1989 to 1991, using Babbage's original plans of this second version, the London Science Museum constructed Babbage's envisaged machine. Faithful to the original designs the machine consists of over 8,000 parts, weighs five tons and measures 3.3m (11ft) in length. In 2000 the printer which he plotted to accompany the engine was added and together performed as the inventor had intended over a century before. The completion of the machine ended a long-standing debate as to whether Babbage's designs would have worked.

Babbage designed the first mechanical computer – the Difference Engine – that eventually led to the invention of the first mechanical computer and as such is widely accepted as the 'father of the computer'.



Despite the fact the machine looks archaic by modern standards the basic architecture is similar to the contemporary computer. The data and program memory are separated, operation was instruction ruled, the control unit could make conditional jumps and the engine had a separate input/output unit.



Charles Babbage

Born in London in 1791, Charles Babbage was a mathematician, philosopher, inventor and mechanical engineer. He was formerly tutored as a child in Devon and Middlesex, and in 1810 he attended Trinity College where he claimed to be disappointed in the mathematical education available. Teaming up with John Herschel and George Peacock, among others, Babbage and company formed the Analytical Society in 1812. In 1814 he married Georgiana Whitmore and moved to Dudmaston Hall in Shropshire where Babbage engineered the central heating system. The couple had eight children, three of which survived to adulthood. In 1827 Charles's wife, father and at least one son died, it was these sad events which caused the inventor to suffer a mental breakdown, delaying the construction of many of his machines. He died aged 79, it is thought of 'renal inadequacy, secondary to cystitis'. Half of his brain is preserved in the Hunterian Museum in the Royal College of Surgeons, London.

Anderson shelter

Named after the head of British Air Raid Precautions during WWII, the Anderson shelter was built to protect civilians from German bombs

The Anderson shelter worked by absorbing the blast and ground shocks from bomb explosions throughout its curved steel sheeting, diverting the potentially dangerous levels of energy released into mere plastic deformation, rather than widespread destruction.

This differed massively from the existing concrete bunkers that had been in use during the early-20th Century as they were especially prone to collapsing if exposed to the effects of a close explosion (both walls and ceiling would collapse if the other was disturbed). Importantly, however, the new shelter was one for the general population and not just the wealthy, with Andersons being released for free if a person earned under £250 a year.

DID YOU KNOW?

The Anderson shelter was designed in 1938 by William Paterson and Oscar Carl Kerrison.

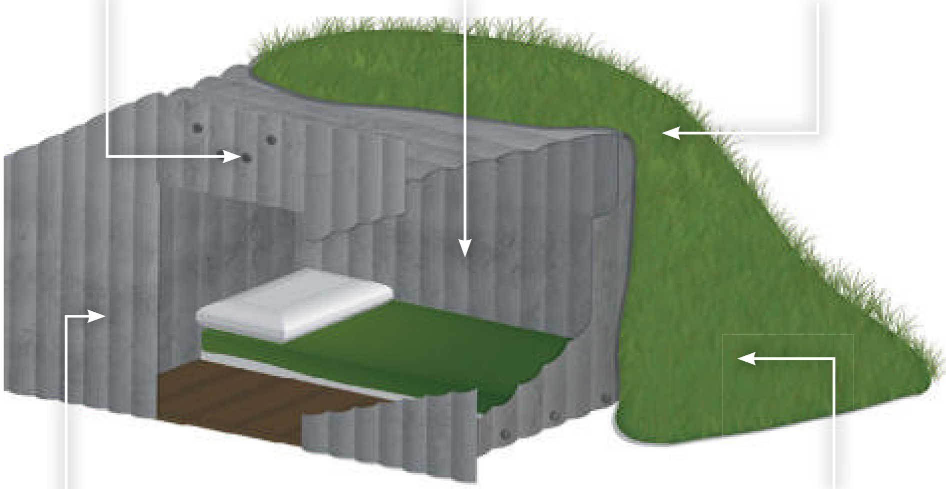
© Ceridwen

A preserved Anderson shelter from 1941

Steel panels
Made from six curved sheets of steel bolted together and with steel plates at either end, the shell of the shelter was 1.95m by 1.35m and could accommodate six people.

Interior
The interior of all Anderson shelters was bare, leaving furnishing to the owner. Because of this, the level of luxury varied massively from shelter to shelter.

Earthen roof
Added as another layer of defence but also to provide camouflage from German bombers, each shelter was, if possible, covered with a great mound of earth.



Blast wall
At the entrance end of the shelter there was both a steel blast sheet and earthen wall to protect it from any debris caused by an explosion to the owners' main dwelling.

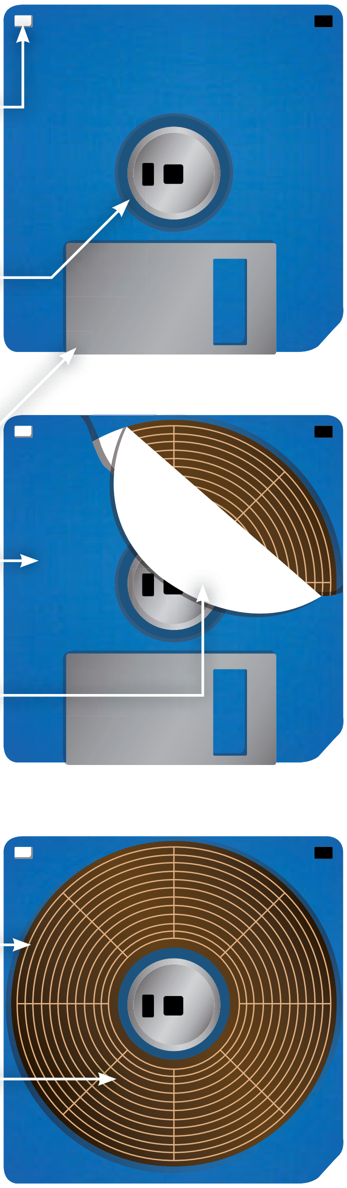
Entrenched
Anderson shelters were entrenched 1.2 metres down into the earth to provide extra protection from explosions and to enhance the stability of the steel-sheeted chassis.

Floppy disks

We take transferring huge amounts of data for granted, but without the floppy disk your USB drives would never have existed

Inside the plastic casing, floppy disks are made from a thin piece of plastic with magnetic material on both sides, arranged in concentric circles like a record, which is in turn divided into sectors. When information is copied to the disk, it spins while a 'stepper motor' matches the rotation and moves a read/write head into place over the correct sector of the disk. Once in place, an erase coil clears the sector of the disk and the read/write head records information onto the disk by magnetising minute, bar-magnet particles embedded in the disk's surface.

What's inside?



Capacity indication
If this hole is present, it means the disk can hold up to 1.4 megabytes.

Hub
This slots on to spokes in the drive to hold the disk steady.

Shutter
This metal shutter protects the disk when not in use.

Plastic housing
The hard outer casing protects the fragile floppy disk interior.

Paper ring
Glued in place, these keep the disk clean as it is spun.

Magnetic disk
This ferromagnetic disk is where the information is recorded.

Disk sector
Each piece of saved information is stored in a different sector of the disk.

Head to Head

WINDMILLS OF THE WORLD

1. Enercon E-126

The largest turbine model built to date, with a hub height of 135m, rotor diameter of 126m and a total height of 198m.

© Jim Woodward-Nutt

2. Outwood post mill

Built in 1665 in Outwood Surrey, this is Britain's oldest working windmill. It was once one of a pair, the other collapsed in 1960.

MOST FAMOUS

© China_Crisis 07

3. Holland's windmills

The Netherlands are so closely associated with windmills that they have become part of their national identity. However, most of these windmills were used for drainage rather than for grinding corn.

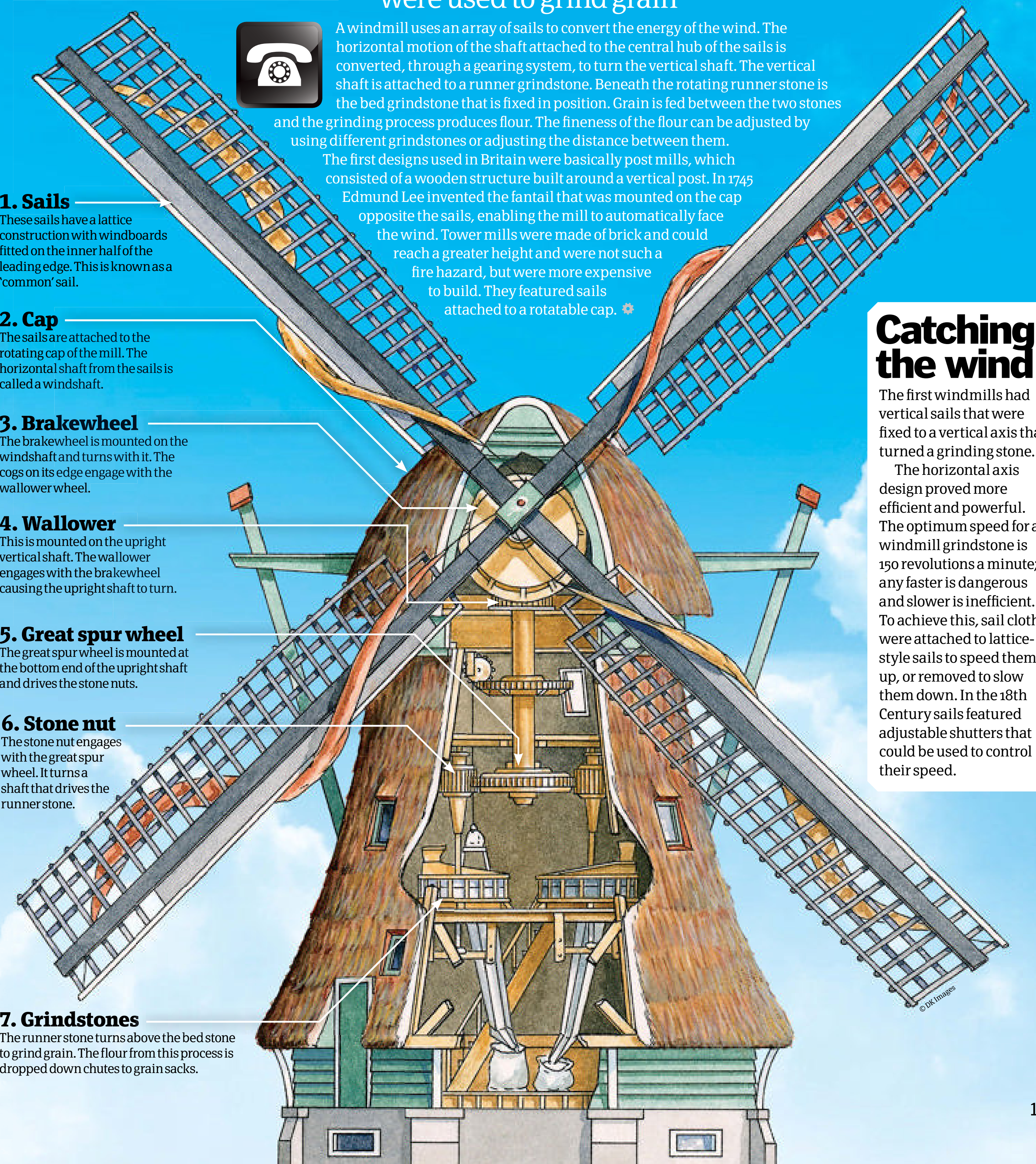
DID YOU KNOW? *Until Henry VIII dissolved the monasteries, villagers had to have their corn ground at their local lord's mill*

Windmills

Before steam and electric power, windmills were used to grind grain

A windmill uses an array of sails to convert the energy of the wind. The horizontal motion of the shaft attached to the central hub of the sails is converted, through a gearing system, to turn the vertical shaft. The vertical shaft is attached to a runner grindstone. Beneath the rotating runner stone is the bed grindstone that is fixed in position. Grain is fed between the two stones and the grinding process produces flour. The fineness of the flour can be adjusted by using different grindstones or adjusting the distance between them.

The first designs used in Britain were basically post mills, which consisted of a wooden structure built around a vertical post. In 1745 Edmund Lee invented the fantail that was mounted on the cap opposite the sails, enabling the mill to automatically face the wind. Tower mills were made of brick and could reach a greater height and were not such a fire hazard, but were more expensive to build. They featured sails attached to a rotatable cap. ⚙



1. Sails
These sails have a lattice construction with windboards fitted on the inner half of the leading edge. This is known as a 'common' sail.

2. Cap
The sails are attached to the rotating cap of the mill. The horizontal shaft from the sails is called a windshaft.

3. Brakewheel
The brakewheel is mounted on the windshaft and turns with it. The cogs on its edge engage with the wallower wheel.

4. Wallower
This is mounted on the upright vertical shaft. The wallower engages with the brakewheel causing the upright shaft to turn.

5. Great spur wheel
The great spur wheel is mounted at the bottom end of the upright shaft and drives the stone nuts.

6. Stone nut
The stone nut engages with the great spur wheel. It turns a shaft that drives the runner stone.

7. Grindstones
The runner stone turns above the bed stone to grind grain. The flour from this process is dropped down chutes to grain sacks.

© DK Images

Catching the wind

The first windmills had vertical sails that were fixed to a vertical axis that turned a grinding stone.

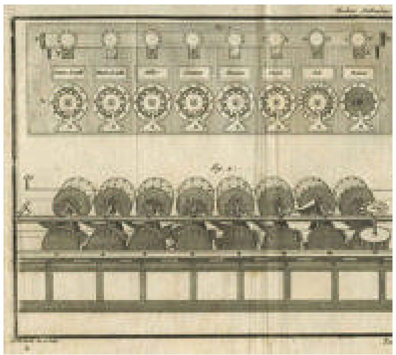
The horizontal axis design proved more efficient and powerful. The optimum speed for a windmill grindstone is 150 revolutions a minute; any faster is dangerous and slower is inefficient. To achieve this, sail cloths were attached to lattice-style sails to speed them up, or removed to slow them down. In the 18th Century sails featured adjustable shutters that could be used to control their speed.

How did early calculators work?

The world's first mechanical number cruncher explained

Blaise Pascal invented his shoebox-sized calculator to assist his father with his business. The Pascal calculator consists of numbered setting wheels that are linked through gears to numbered drums. From the left each wheel represents units of 1, 10, 100, 1,000, 10,000 and 100,000. To add 4 and 9, you dial 4 on the first wheel, and then dial 9. After reaching 9, the gearing mechanism turns the drum in the second window representing units of 10 to 1. The machine then displays 13 as the answer. For use with French currency, the first two wheels are fitted with 12 and 20 spokes to represent deniers and sols, with the remaining wheels counting livres. It is possible to use the device to subtract numbers (using the nines complement method), multiply by using repeated addition, or divide numbers by using repeated subtraction. Unfortunately, its complexity and cost hampered its widespread use.

©2005 David Monniaux


Top and inside view of an eight-digit Pascal calculator. Note the first two windows calculate sols and deniers

Plough parts

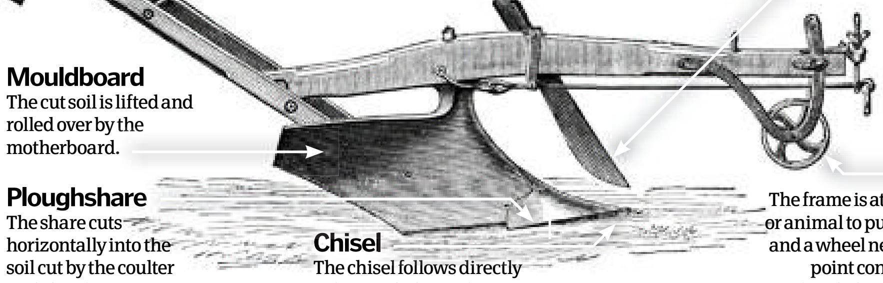
The essential tool for cultivating the land

The first plough was no more than a stick dragged in the ground. The ancient Egyptians developed the use of animals like oxen or cows to pull a plough, and the Greeks added wheels to this design for greater control and manoeuvrability.

Ploughs simply moved aside the soil to break it up and create a furrow to plant seeds into, but in the 1600s, the Dutch improved ploughs using a mouldboard that turns over the top soil and deposits it over the previous furrow. This design was more efficient and easier to use, allowing more land to be cultivated.

© Ralf Roletschek 2004

The mouldboard plough



Coulter
This is either a knife or disc that cuts vertically into the soil. It is essential for ploughing heavy soil.

Mouldboard
The cut soil is lifted and rolled over by the motherboard.

Ploughshare
The share cuts horizontally into the soil cut by the coulter and chisel.

Chisel
The chisel follows directly in line with the coulter.

Frame
The frame is attached to a vehicle or animal to pull it along the field, and a wheel near the attachment point controls the depth the ploughshare moves in the soil.

Self-heating food cans

Discover the easy way to heat and eat

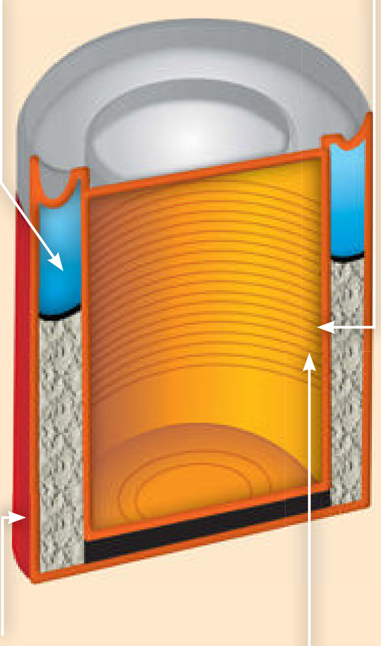
Wilhelm Espenhayn and Friedrich Oswald Hunger gained a US patent for a self-heating can in 1906, and the principles of its operation have barely changed since. The can itself essentially consists of two outer or inner compartments, one containing quicklime (calcium oxide CaO), and the other containing water. To heat the food or drink inside the can, the seal between the two compartments is broken.

Within seconds, the two substances create an exothermic reaction, which means they release energy in the form of heat. In the space of five minutes, this reaction will heat the can's contents to 40 degrees Celsius.

Inside the self-heating can

Water
Water is contained in a compartment surrounding the upper part of the standard food can.

Quick lime
This is contained in a compartment surrounding the lower part of the can.



Insulation
A heat insulator surrounds the can to prevent heat radiating outwards and away from the contents of the can.

Seal
A waterproof seal separates the water and quicklime compartments.

5 TOP FACTS
1804 STEAM LOCOMOTIVE

Wager
1 The 1804 Steam Locomotive completed its 15.7km (9.75mi) run up the Merthyr Tydfil Tramroad in four hours five minutes, winning owner Samuel Homfray 500 guineas.

Hammertime
2 The 1804 Locomotive used one of Richard Trevithick's high-pressure steam engines to run. The engine in question was built in 1802 by Trevithick to drive a hammer.

Need-to-know
3 During the record run, the locomotive's passengers included Samuel Homfray, iron merchant Richard Crawshay, and also an 'engineer from the government'.

In and out
4 Penydarren ironworks was founded in 1784. Despite being the last great ironworks to be built in the Merthyr area of Wales, it was the first to close in 1859.

Insanity
5 Richard Trevithick was branded with 'folly and madness' by engineer James Watt for attempting to use the high-pressure steam engines to power his 1804 Locomotive.

DID YOU KNOW? *The 1804 Steam Locomotive had an average speed of 3.8km/h (2.4mph)*

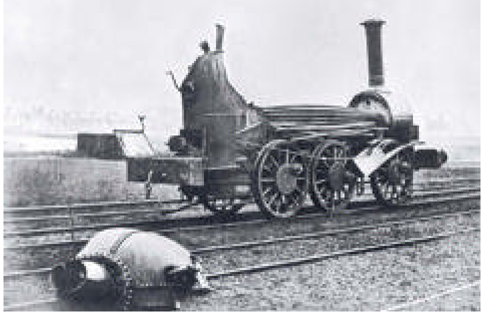
1804 Steam Locomotive

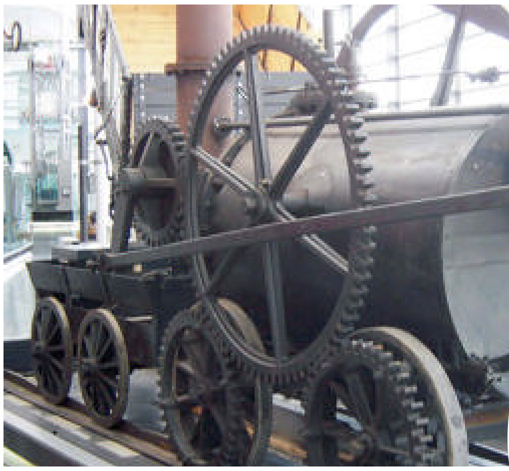
Heralding the age of the Industrial Revolution, the 1804 Steam Locomotive demonstrated the awesome potential of steam power

Richard Trevithick's 1804 Steam Locomotive worked by partnering a high-pressure steam boiler with a single, large cylinder and piston to drive a set of wheels. The engine operated in four stages: first, coal was heated and burned within a firebox at the rear of the engine, second that fire was used to heat the engine's water tank in order to generate steam, which in turn was then filtered into the unit's cylinder causing a piston to be driven back and forth, before finally channelling that mechanical energy into the train's wheels to generate forward momentum.

The locomotive was built after its patent owner (bought off Trevithick) Samuel Homfray – owner of the Penydarren ironworks in South Wales – undertook a wager with rival ironmaster Richard Crawshay for 500 guineas. The bet was whether or not Trevithick's Steam Locomotive could haul ten tons of iron over the nine miles of the Penydarren tramway to Abercynon, where the mine's iron was transferred to barges for wider distribution throughout Britain.

Completed by Trevithick, the steam engine weighed over five tons with a fully loaded water tank – a fact that would later lead to parts of the tramway to buckle under immense weight – and had a top speed of five miles per hour. Despite its stately pace and extreme weight, however, the 1804 Steam Locomotive successfully completed its impressive journey on 21 February, obliterating the set load weight by pulling 25 tons of iron along with 70 passengers, both winning Homfray his money and paving the way for steam-powered engines to be used widely in the upcoming century's industrial transformation.

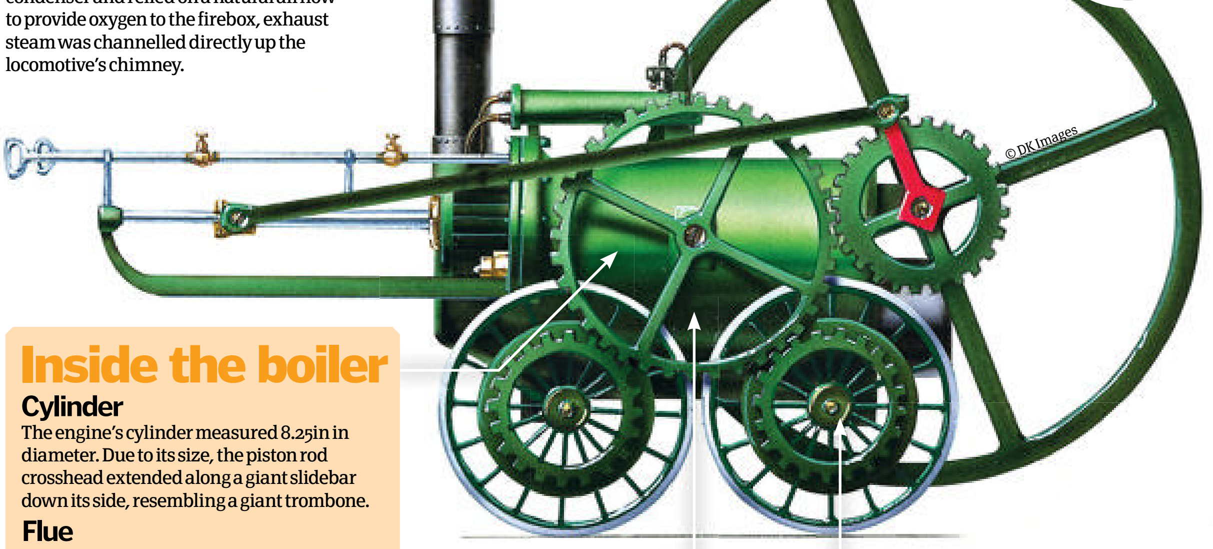

A shot of a wrecked, high-pressure steam train from 1850. Here the boiler has exploded, sheering off the top half


Penydarren ironworks was the start point of the 1804 Steam Locomotive's journey

© Chris 55

Richard Trevithick

The locomotive components


© DK Images

Chimney
Due to the fact the engine did not use a condenser and relied on a natural airflow to provide oxygen to the firebox, exhaust steam was channelled directly up the locomotive's chimney.

Inside the boiler

Cylinder
The engine's cylinder measured 8.25in in diameter. Due to its size, the piston rod crosshead extended along a giant slidebar down its side, resembling a giant trombone.

Flue
In order to adequately heat generated steam it had to be passed through a flue (heating pipe) in the engine for a set amount of time. However, due to the compact nature of the locomotive's boiler tank, this meant the flue had to be U-shaped.

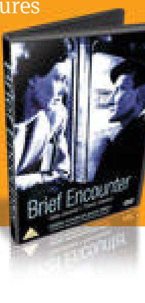
Boiler
Trevithick's 1804 Steam Locomotive was powered by a high-pressure, wrought iron boiler without a condenser. When the boiler was full of water, the engine weighed a whopping five tons.

Wheels
Mounted on the side of the engine was a flywheel that was used to even out the movement and speed of the piston rod and crosshead, which was then transferred to the locomotive's central cogwheel and onto the driving wheels.

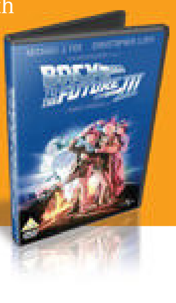
Steam power in the movies

Although we may have moved on from steam power in a number of areas, there will always be a place for it on the silver screen…

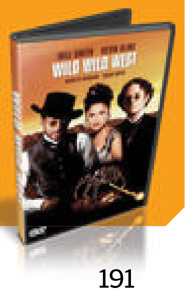
Brief Encounter
Brief Encounter features a variety of steam trains constantly coming and going through the station in which the film's two protagonists rendez vous.



Back To The Future III
Trapped back in 19th Century America, Marty McFly and 'Doc' Brown have to use a steam train to push the DeLorean up to its magical 88mph.



Wild Wild West
Wild Wild West sees Smith and Kline travel round in their own steam train. It also features a steam-powered spiderbot that can shoot fireballs.



Wild west w

The development of reliable, accurate pistols and rifles played a key part in how the west was won

During America's frontier past, westward expansion meant settlers had to protect themselves and the land they had taken from Native Indian reprisals. Chief concern, the Comanche, could lose nine arrows in the time the Texans took to muzzle-load and fire a musket. The revolving cylinder pistol and lever-action repeating rifles marked the turning point in this battle. Of these, while the black powder .36 calibre 1851 Paterson Colt failed to unseat the mounted Comanche, the Walker Colt, adopted by the Texas Rangers in the 1850s, did not.

The Volcanic repeating rifle fired caseless ammunition known as a 'rocket-ball'. The powder and primer was fused by a binding agent in the hollow rear of the bullet. Unlike the black powder handguns that used paper/cloth cartridges that were susceptible to moisture and so prone to misfire, the rocket-ball was waterproof. Unfortunately, the ammunition – despite its name – was grossly underpowered; it was usurped by the Henry and Winchester rifles of the 1860s.

By the 1870s revolvers benefited from enclosed metal-cased bullet cartridges, which meant all-weather shoot-outs. Their common centerfire rounds were compatible with many Winchester lever-action rifles, allowing the holder to alternate firearms with ease. These modern cartridges and later pistol designs gave rise to Colt's game-changing Single Action Army 1873. The "Peacemaker" ushered in the typical pistol fighting genre with the line: "God didn't create all men equal, Sam Colt did". ⚙

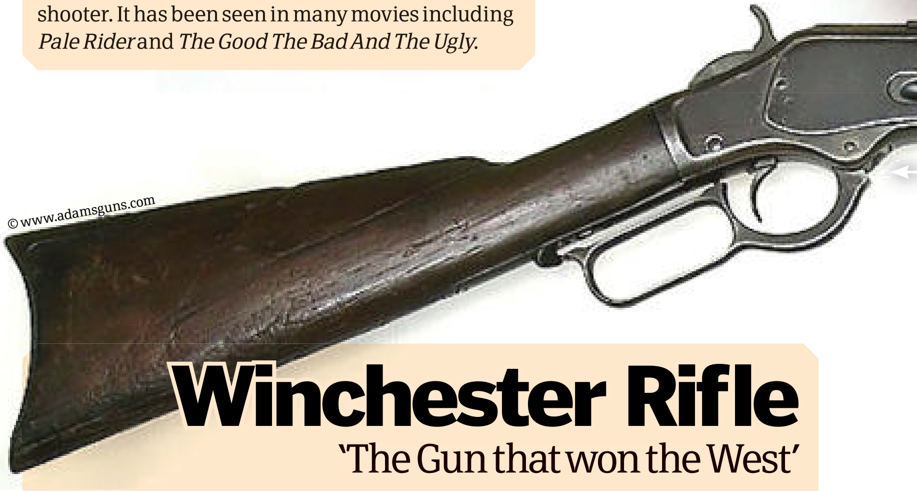
© DK Images

Round bullets
The six chambers could be loaded by dropping in powder charge followed by a round or conical bullet.

Remington .44

A sturdier and more accurate competitor to the Colt

The Remington Army revolver was a large-framed .44 calibre, with an eight-inch barrel length. It had a six shot cylinder and an eight-inch octagonal barrel. Patented in 1858, it was the major competitor to the Colt .44 in the American Civil War, and many considered it to be more accurate than the Colt. The percussion model could be easily modified to accept cartridges prior to the introduction of the first Remington cartridge revolver in 1875. These percussion revolvers were capable of considerable power with muzzle velocities in the range of 550 to 1,000+ feet per second depending on the charge loaded by the shooter. It has been seen in many movies including *Pale Rider* and *The Good The Bad And The Ugly*.



© www.adamsguns.com

Winchester Rifle

'The Gun that won the West'

The Winchester 1866 succeeded the Henry rifle. Its 'lever-action' mechanism and distinctive side-loading gate allowed the shooter to eject spent cartridges and chamber new rounds from a sealed tubular magazine, all in one movement.

The rifling process, whereby spiral grooves are etched into the gun barrel, helped to impart spin on the passing bullet, enhancing its accuracy in flight.

The 1866 shot .44 rimfire cartridges while the 1873 and later designs chambered 0.44, 0.38 and 0.32 centerfire rounds; used by Colt, Remington and other revolvers. The replaceable primer located in the central base of the cartridge rather than built into the rim meant when struck and ignited the casing could be re-used; an advantage for large rifles where ammunition was expensive.

Brothers in arms

The Clanton and McLaury clan's defiance of Tombstone gun-carrying laws ended in a 15ft space of William Harwood's lumberyard. From the OK Corral, Town Marshall Virgil Earp's call to disarm could be heard; sparking the 19-year old Billy Clanton to draw against Wyatt and miss. The resulting firefight saw Morgan Earp's reply hit Clanton twice in the chest. Wyatt's .44 calibre Smith and Wesson turned on the stomach of Frank McLaury, while unarmed, his younger brother Tom and Ike Clanton tried to run. Ike escaped, but Tom McLaury was hit in the back by a shotgun loaned to Holliday. In just 30 seconds all but Ike from the cowboys were left dying, or dead.

Shooting from the hip

1. **Technique:** Draw pistol up, inches from holster; rotate wrist and lower elbow; move gun forward and up towards target; steady with supporting arm and fire!
2. **Weapon of choice:** Walker Colt's weight did not lend itself to quick draw, unlike the SAA Peacemaker 1873.
3. **A good workman:** Considered by many the fastest, the Sundance Kid (1890s) would be more deadly, accurate, and quicker, because of his tools, than Jesse James (1870s) - but this didn't factor in meanness or even a man's will!
4. **The meanest:** John Wesley Hardin; with over 40 kills to his name was reputed to have killed a man simply for snoring!

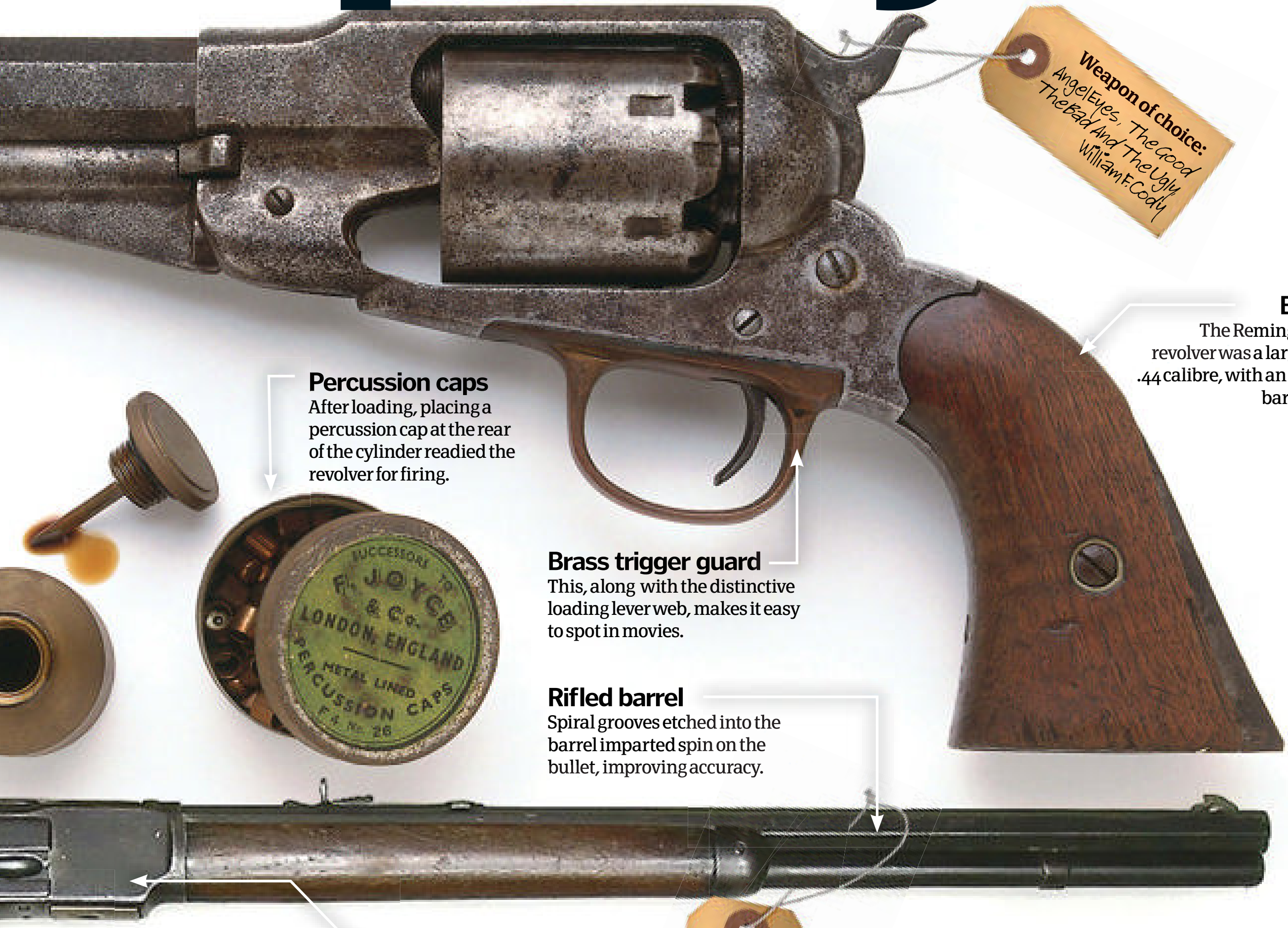
DID YOU KNOW?

Gunning for glory

The Winchester 1866, nicknamed 'Yellow Boy' due to its brass receiver, was no coward; the Winchester would come to be known as "the gun that won the west".

DID YOU KNOW? *The gunfight near the OK Corral took place at approximately 3pm on Wednesday 26 October 1881*

veaponry



Big gun!
The Remington Army revolver was a large-framed .44 calibre, with an eight-inch barrel length.

Percussion caps
After loading, placing a percussion cap at the rear of the cylinder readied the revolver for firing.

Brass trigger guard
This, along with the distinctive loading lever web, makes it easy to spot in movies.

Rifled barrel
Spiral grooves etched into the barrel imparted spin on the bullet, improving accuracy.

Lever action
This mechanism allowed a round to be ejected and a new one chambered in one movement.

Side gate
The loading gate on the side and integrated, round sealed magazine covered by a forestock.

Cylinder
Housing a cluster of six to ten barrels which were loaded by a hopper.

Crank
The Gatling Gun required an operator to crank, so it's not a true automatic.

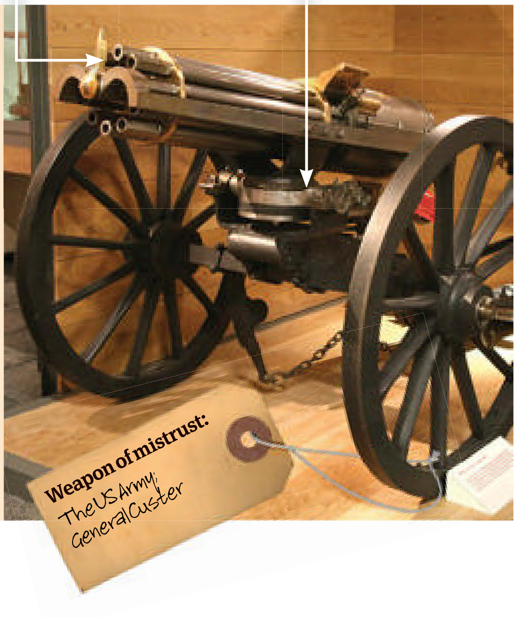
Gatling Gun

Slaughter… with the best of intentions

Gatling's aim was to reduce the need for large armies, and so exposure to battle. However, despite dispensing a murderous 400-1,200 0.45-1 calibre rounds/per min. this gun was initially unpopular. At 90lbs the US Army thought it too unwieldy for combat.

Its cylinder housed a cluster of six to ten barrels turned by a crank shaft; loaded upon rotation by a gravity-fed ammunition hopper. Each barrel had its own breech and a firing-pin mechanism aligned in a groove in the gun's body. As the barrel rotated the groove pulled the pin backwards, compressing its spring. As a cartridge fell into the breech of the barrel the firing-pin slid from the groove causing the pin to shoot forwards, contacting the cartridge and dispensing its round.

General Custer refused its use in his final fight at the Battle of Little Bighorn. It was only used late in the war against the North.



Head to Head

LAST MAN STANDING

More often than not gunfights were visceral spur-of-the-moment encounters sparked by disagreements and fuelled by drink that bore little relation to the honour and romantic idyll of quick-draw.

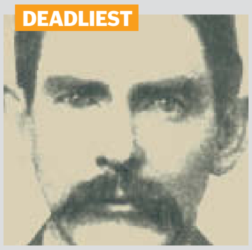
DEAD (CLEVER)

1. Billy the Kid
A renowned gunslinger he was not below tricking opponents to gain an advantage. On the wrong end of a battle of wits he was shot from the shadows by lawman Pat Garrett aged just 21.

DEADLIER

2. Wild Bill Hickok
Hickok killed more than 20 men during gunfights; he would reload his 1851 Colt black powder revolver every morning (even if it hadn't been used) to prevent moisture and a resulting misfire.

DEADLIEST



3. Doc Holliday
Wyatt Earp claimed Holliday was "the nerviest, fastest, deadliest man with a six-gun I ever saw!" Earp lived to the ripe age of 81. Enough said.

Learn more

For more information on the weapons that won the West, along with a detailed look at the history of arms and armour, the DK book *Weapon*, produced in association with the Royal Armouries Museum, is available from **www.amazon.co.uk**.

The gramophone explained

The invention that brought sound to the home

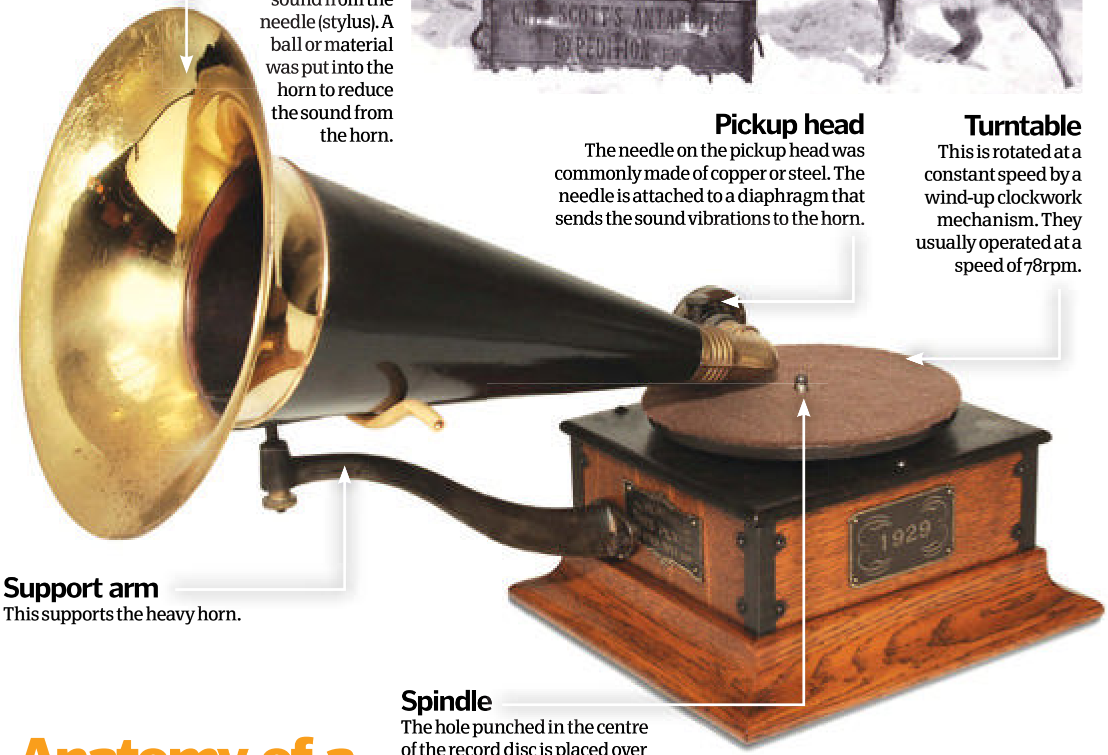
In the 19th Century, there was fierce competition in Europe and the USA to create machines that could record and playback music and sounds. As early as 1857, the phonautograph, created by Édouard-Léon Scott de Martinville, used a diaphragm attached to a bristle that responded to sound vibrations. These vibrations were traced onto a sheet of paper coated in soot, which was wrapped around a rotating cylinder. This, however, could not play back the recording.

In 1877, Thomas Edison's phonograph followed a similar principle to the phonautograph, but used tinfoil wrapped over a grooved cylinder. The vibrations of a needle attached to a diaphragm and horn made indentations in the foil, and to play it back the needle retraced the indentations in the foil. Wax cylinders enabled such recordings to be played back more than once.

Ten years later, Emil Berliner introduced the gramophone that used discs with a spiral groove, rather than a cylinder to record and play back the sound. It still used a horn and needle, but unlike cylinders, the master recording could be easily copied onto a mould and mass-produced. The gramophone came to dominate the market in the Twenties, superseded by the electronic record player.

Sled dog and gramophone, Terra Nova Expedition

Anatomy of a gramophone



Horn
Amplifies and projects the sound from the needle (stylus). A ball or material was put into the horn to reduce the sound from the horn.

Pickup head
The needle on the pickup head was commonly made of copper or steel. The needle is attached to a diaphragm that sends the sound vibrations to the horn.

Turntable
This is rotated at a constant speed by a wind-up clockwork mechanism. They usually operated at a speed of 78rpm.

Support arm
This supports the heavy horn.

Spindle
The hole punched in the centre of the record disc is placed over the spindle. This keeps the record from spinning off the turntable as it rotates.

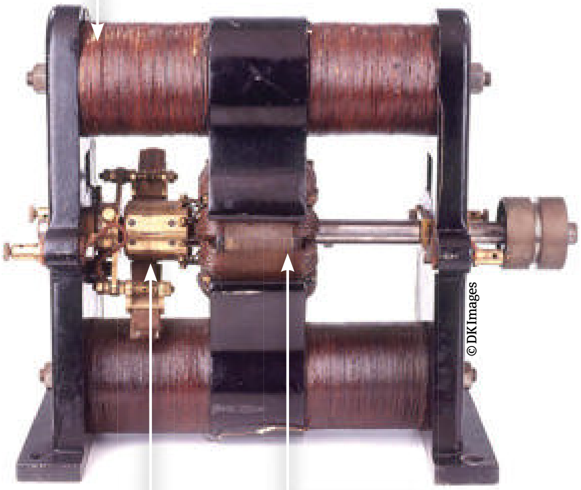
How do dynamo generators work?

Revolutionising the generation of electricity, dynamos are now used worldwide to power cars, planes and ships

A dynamo electric generator converts mechanical energy into electrical energy. It rotates coils of metal wire (the mechanical energy) within a magnetic field to force the field to push on the electrons in the metal and vary its flux (amount of field passing through the coils). This, as according to Faraday's law – the induced electromotive force in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit – causes the induction of electric current (electrical energy).

Therefore, dynamos have three main components – the stator, armature and commutator. The stator is a stationary structural frame that provides the dynamo's constant magnetic field, while the armature is the dynamo's central set of wire windings that are rotated by mechanical energy. The commutator is a rotary electric switch that is mounted to the armature's central shaft and reverses the electrical potential within the wire with each half turn of the armature, to convert alternating current into direct current.

Today, direct current dynamos are rarely used, due to the worldwide dominance of alternating current and its ease of conversion using solid-state materials.

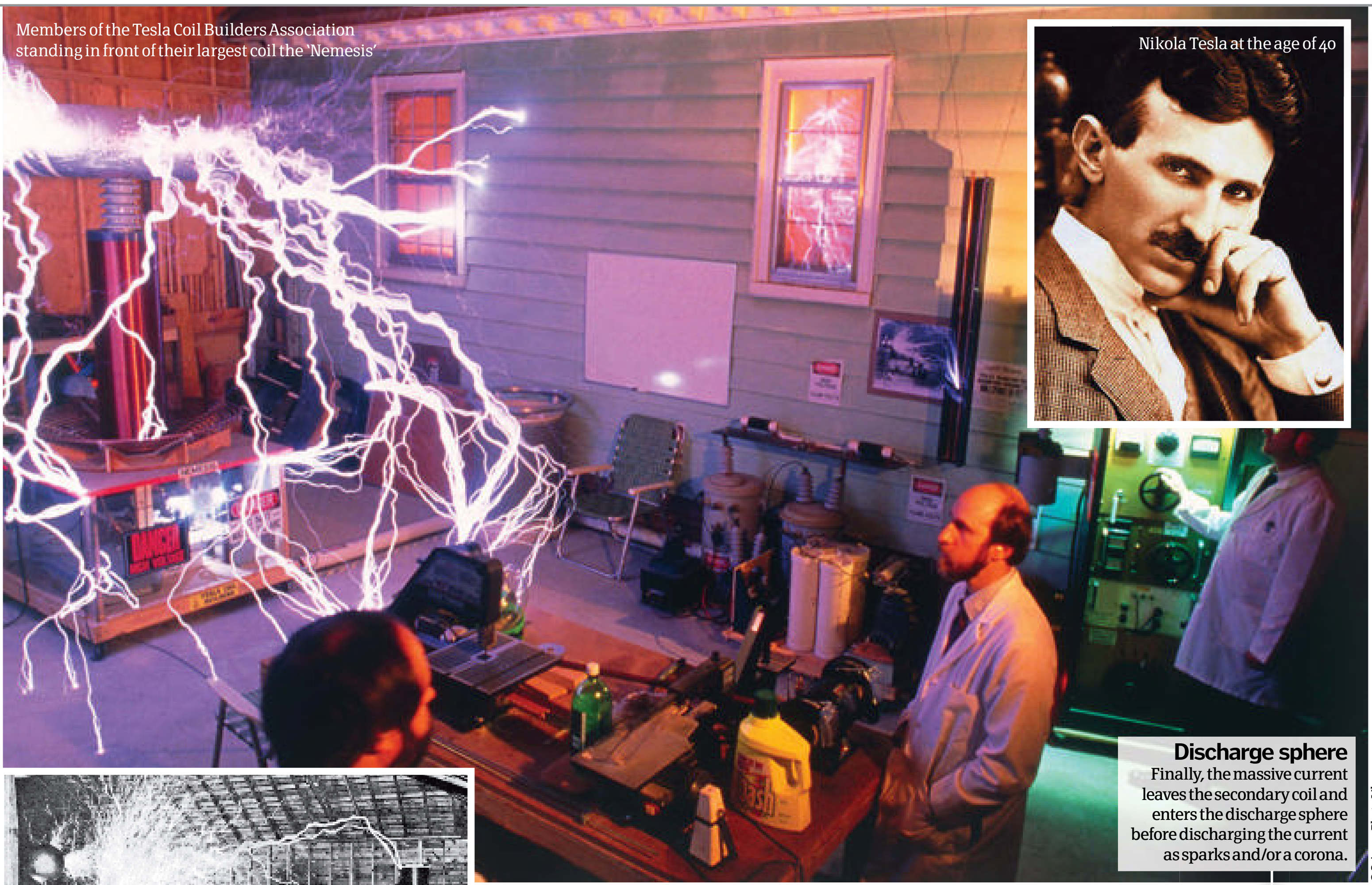


© DK Images

Stator
A stationary structure that provides a constant magnetic field for the armature to rotate in.

Commutator
A rotary electric switch that reverses the current direction within the armature.

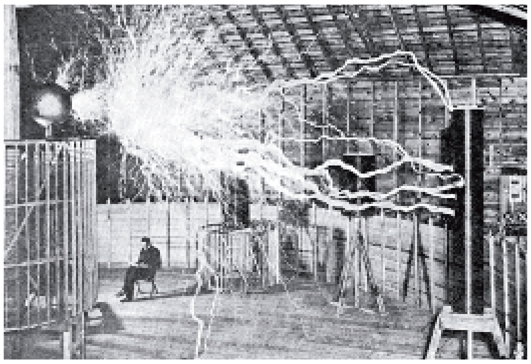
Armature
A set of wire windings that rotate within the stator's generated magnetic field to induce current.



Members of the Tesla Coil Builders Association standing in front of their largest coil the 'Nemesis'

Nikola Tesla at the age of 40

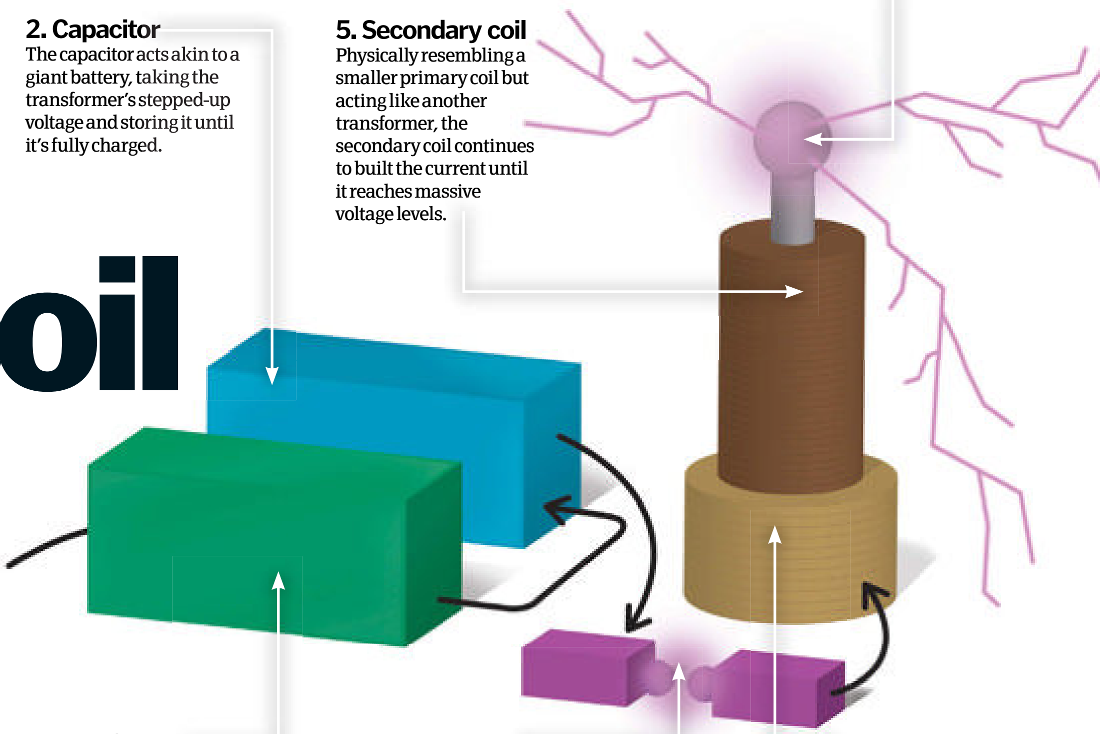
©Science Photo Library



Tesla coil

One of the first and most theatrical resonant transformer circuits ever

An early type of resonant transformer – a device that facilitates the wireless transference of energy between two similarly tuned coils – Nikola Tesla's coil worked by stepping up a current exponentially to produce high voltage, high current and high frequency alternating current electricity. During the operational life span (1890s – 1920s) Tesla coil circuits were primarily used commercially in radio transmitters for wireless telegraphy and medical devices for electrotherapy. Follow this step-by-step guide to see how the famous coil worked.



1. Transformer
The initial transformer takes a low-level current and steps it up to thousands of volts.

2. Capacitor
The capacitor acts akin to a giant battery, taking the transformer's stepped-up voltage and storing it until it's fully charged.

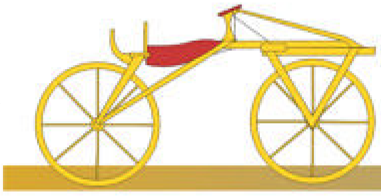
3. Spark plug
When the capacitor reaches 100 per cent, the spark plug fires releasing its contents into the large primary coil.

4. Primary coil
Made from a thick copper wire, the primary coil produces a strong magnetic field as the current released by the spark plug flows through it.

5. Secondary coil
Physically resembling a smaller primary coil but acting like another transformer, the secondary coil continues to built the current until it reaches massive voltage levels.

Discharge sphere
Finally, the massive current leaves the secondary coil and enters the discharge sphere before discharging the current as sparks and/or a corona.

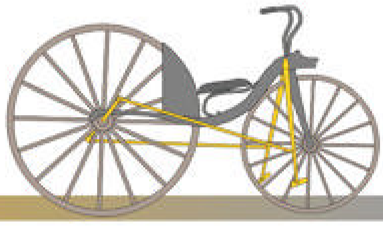
1817



© Author: Al2, 2007

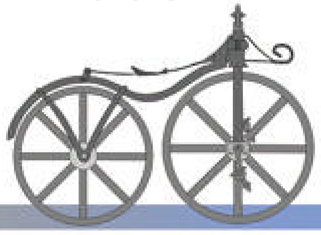
Walking machine
Invented by Baron von Drais in 1817. You sit in the middle of two similar sized wheels, and roll along by walking on the ground.

1865



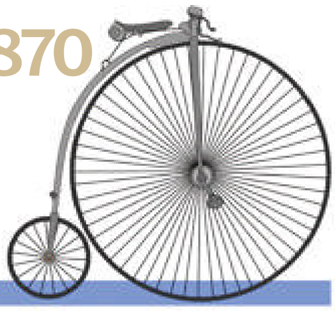
Velocipede
In 1865 crank-driven pedals were fitted on the front wheel of a walking machine-like bicycle. It was very bumpy to ride.

1868



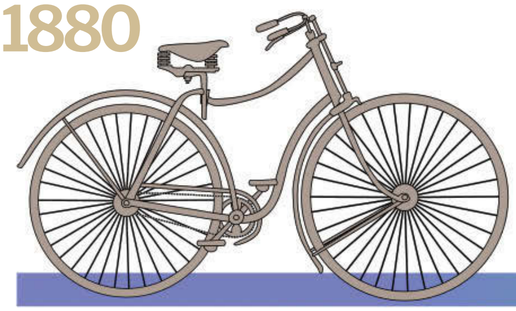
Pedal bicycle
Pierre Michaux formed a company that was the first to produce bicycles with pedals on a large scale.

1870



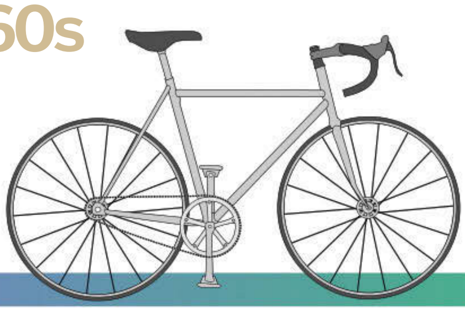
High wheel
In 1870 came this machine. The rider sat above the large wheel, which had pedals on the front wheel to propel it forwards.

1880



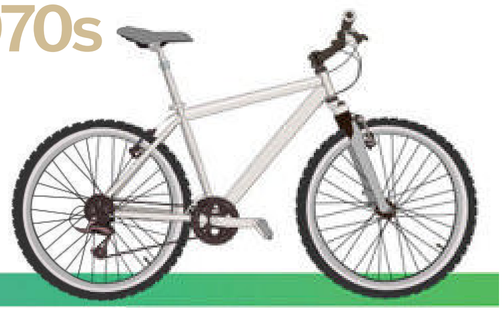
Safety bicycle
Stronger metal frames and the use of chains and gears made same-sized two-wheeled bicycles more viable in the 1880s.

1960s



Racing bicycle
For maximum aerodynamic performance they feature lightweight frames, drop handlebars and fine gearing.

1970s



Mountain bike
Developed for off-track racing. To cope with rugged terrain they have either front or rear suspension.

The evolution of the bicycle

Discover the development of the bike through the ages

The name bicycle was a term coined in 1869. However, bicycle-like machines were built much earlier during that century. The walking machine of 1817 may not have possessed pedals, but it did have a steerable handlebar and was used throughout Europe. In Britain they were known as 'hobby horses'.

Before the introduction of such snazzy features as pedals and chain drives, Kirkpatrick Macmillan invented a push rod system which he used for propelling his bicycle. The idea was that you had to push your feet up and downwards to drive the rear wheel. The introduction of pedals on the velocipede kick-started the evolution of today's bicycle.

One turn of the pedals equalled one turn of the bicycle wheel, making the rider pedal furiously to obtain any speed. To overcome this problem the high wheel bicycle had the pedals attached to a large wheel, so that the bicycle covered a far greater distance on one turn of the pedals.

By the end of the 19th Century tricycles and safety bicycles featured many new innovations; lighter steel-tubed frames, brakes, pneumatic tyres, metal-link chains that connected the pedals to a toothed sprocket on the rear wheel and gearing systems that employed several different sized sprockets to change the ease or difficulty of turning the pedals.

These technological innovations enabled urban dwellers to commute or travel to the countryside more efficiently and quickly. In particular, bicycles gave women far greater independence. In the Thirties, a combination of lower production costs and rising wages made bicycles much more affordable for the working classes and their recreational use began to increase.

Evolution of the wheel

Since its invention, how has the wheel developed over the years?

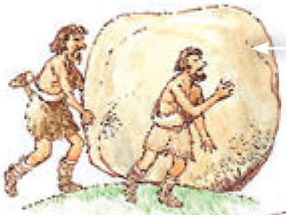
Early humans in the Palaeolithic era (15,000 to 750,000 years ago) discovered that heavy, round objects could more easily be moved by rolling them than bulky, irregular ones. The realisation was made that some heavy objects could be transported if a round object such as a fallen tree was placed underneath and the heavy object rolled over it. However, diagrams on ancient clay tables suggest the wheel did not materialise for thousands of years until a potter's wheel was used in Mesopotamia (modern day Iraq) in 3500 BC.

The oldest wheel discovered so far was found in Ljubljana, Slovenia and is believed to date back to about 3200 BC, remarkably late for such a key invention. It was about the same time that the wheel was first used for transportation on chariots. With a need for greater speed and manoeuvrability, the Egyptians created the spoked wheel around 2000 BC, while Celtic chariots a millennium later employed iron rims for greater strength. However, the wheel remained largely unimproved until the 19th Century when Scot Robert William Thompson invented the pneumatic tyre, a rubber wheel using compressed air which paved the way for automobile and bicycle tyres.

DID YOU KNOW? The world's highest Ferris wheel is in Singapore and rises 165 metres. That's almost twice as high as Big Ben.

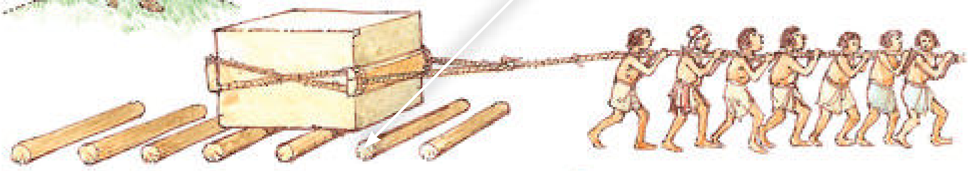
Wheels through the ages

The wheel has been used extensively and improved upon throughout time but how have humans harnessed its practicality?



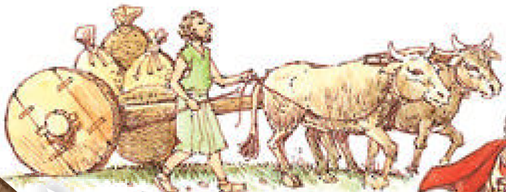
1. Keep rollin'

Early Homo sapiens realised that round objects could be easily moved by rolling them.



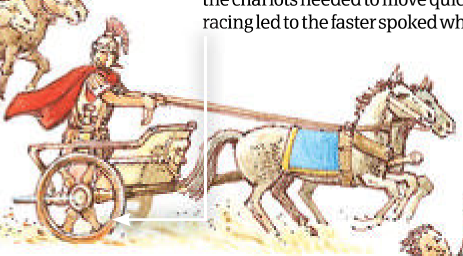
2. Logs away

Their ancestors advanced this rolling technique into the transportation of large objects on cylindrical logs.



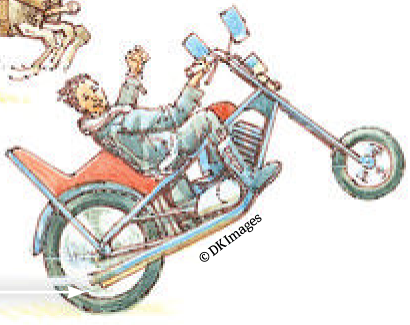
3. A wheel of a time

The invention of the wheel and axle allowed a rolling log to be placed through a hole in a wheel to create a cart.



4. Chariots of tyre

Influential in the evolution of the wheel as the chariots needed to move quickly, chariot racing led to the faster spoked wheel.



5. Wheel easy

The invention of air-filled rubber tyres allowed wheels to be much faster, sturdier and stronger, ultimately redefining transportation.

© DK Images

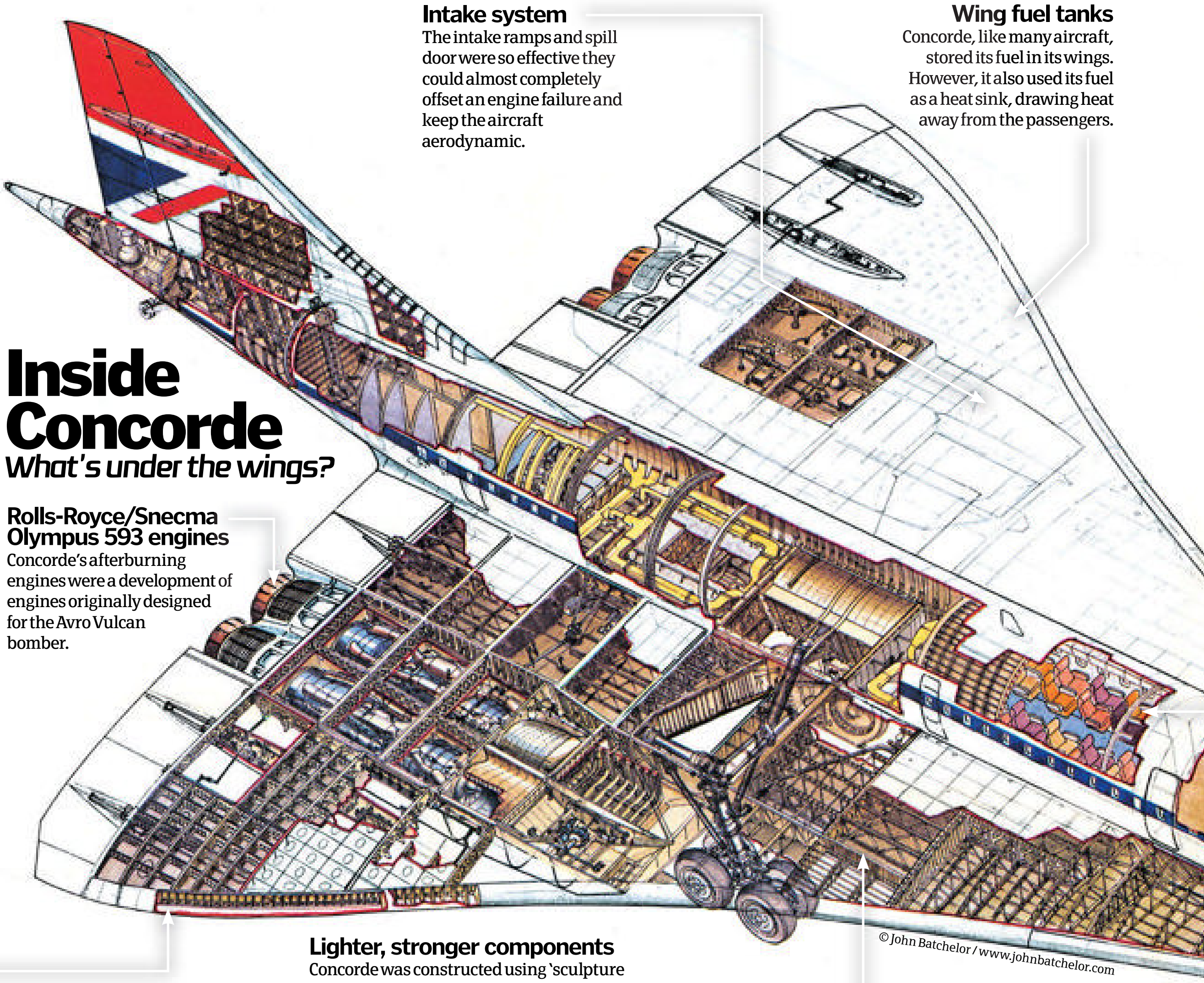
Spokes help support the weight of the load on a vehicle

DANGER
DANGER

© DocKurt2K

Inside Concorde

What's under the wings?



Intake system
The intake ramps and spill door were so effective they could almost completely offset an engine failure and keep the aircraft aerodynamic.

Wing fuel tanks
Concorde, like many aircraft, stored its fuel in its wings. However, it also used its fuel as a heat sink, drawing heat away from the passengers.

Rolls-Royce/Snecma Olympus 593 engines
Concorde's afterburning engines were a development of engines originally designed for the Avro Vulcan bomber.

Ogival wings
Concorde's 'double delta' wings helped its aerodynamic profile and speed.

Lighter, stronger components
Concorde was constructed using 'sculpture milling', a process that reduced the number of parts required while making those that were necessary lighter and stronger.

© John Batchelor / www.johnbatchelor.com

Concorde

An aircraft that could fly across the Atlantic in less than three hours seemed as impossible as it was desirable

Flying faster than the speed of sound has always been the sole proviso of the military, but in the late-Sixties, Russia, France, the UK and the US were all working on the idea of supersonic commercial travel. Faster planes meant shorter travel times, increased demand and higher prices.

Concorde was the result of France and the UK combining their efforts to produce a supersonic airliner and, even now, it's impossible not to be impressed by its pioneering stature.

Its ogival or double-curved wings kept it aerodynamic and dictated much of the plane's shape, as they forced the nose up on taxiing, take off and landing. To help minimise drag on the aircraft as well as improve visibility, the nose cone could move, dropping down to improve visibility then straightening out in flight to improve the aerodynamic profile.

Concorde's engines also had to be modified for extended supersonic flight. Jet engines can only take in air at subsonic speed so the air passing into the engines had to be slowed when flying at Mach 2.0. Worse, the act of slowing the air down generated potentially damaging shock waves. This was controlled by a pair of intake ramps and an auxiliary spill door that could be moved during flight, slowing the air and allowing the engine to operate

Head to Head SUPERSONIC PLANES

THE FIRST

1. Bell X-1

As well as being the first aircraft to break the speed of sound, the X-1 was the first in a long line of experimental, pioneering aircraft.

THE FASTEST

2. SR-71 Blackbird

A futuristic, high-altitude reconnaissance aircraft, the SR-71 was capable of up to Mach 3.35, or 2,275 miles per hour.

THE FAILURE

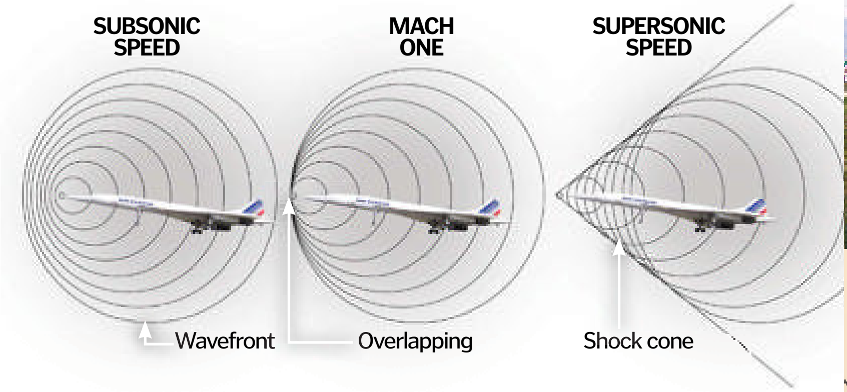
3. Tupolev-144 (NATO code name – Charger)

The TU-144 flew two months before Concorde in December 1968 but was ultimately scrapped due to lack of demand.

DID YOU KNOW? *The first Concorde test flight took place from Toulouse on 2 March 1969*

The sonic boom

Sonic booms are generated by the passage of an object through the air. This passage creates pressure waves that travel at the speed of sound. The closer the aircraft gets to the speed of sound, the closer these waves become until they merge. The aircraft then forms the tip of a 'Mach cone', the pressure wave at its nose combining with the fall in pressure at its tail as it passes to create the distinctive 'boom' sound.



This Concorde is on display at Paris-Charles de Gaulle airport

End of an era

On 25 July 2000, Air France Flight 4590 crashed in Gonesse, France, killing all 100 passengers and nine crew as well as a further four on the ground. Although the crash was caused by a fragment from the previous aircraft to take off, passenger numbers never recovered and were damaged still further by the rising cost of maintaining the ageing aircraft and the slump in air travel following the 9/11 attacks.

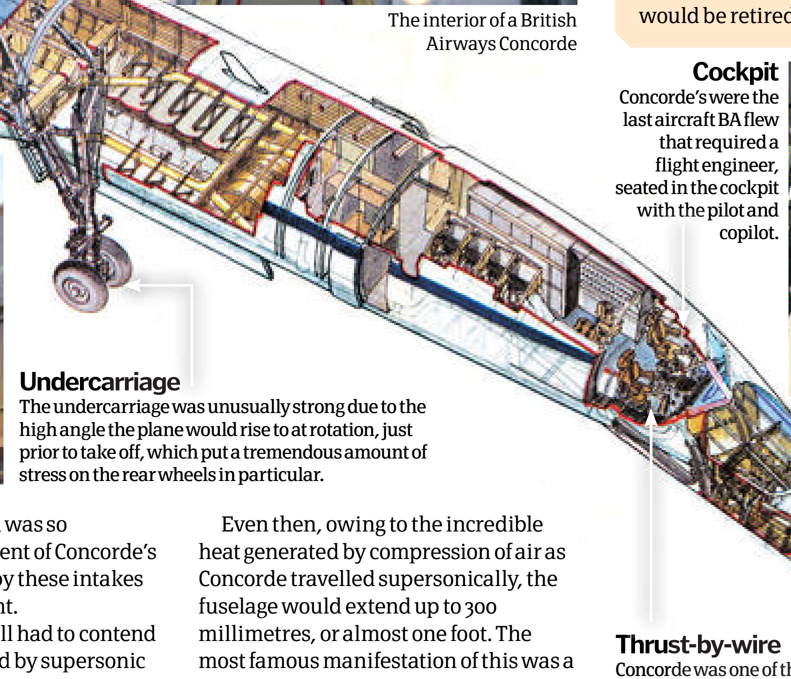
As a result, on 10 April 2003, Air France and British Airways announced their Concorde fleets would be retired later that year. Despite an attempt by Richard Branson to purchase BA's Concorde fleet for Virgin Atlantic, the planes were retired following a week-long farewell tour that culminated in three Concordes landing at Heathrow. BA still owns its Concorde fleet: one is on display in Surrey, a second is being kept near-airworthy by volunteers at the Le Bourget Air and Space Museum, and a third, also at that site, is being worked on by a joint team of English and French engineers. The plan is to make it air worthy and have the aircraft form part of the 2012 Olympics opening ceremony.

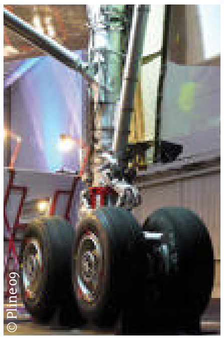
Passenger cabin

Concorde could carry 92 passengers or be reconfigured internally to carry up to 120.

© Martin J. Galloway

The interior of a British Airways Concorde





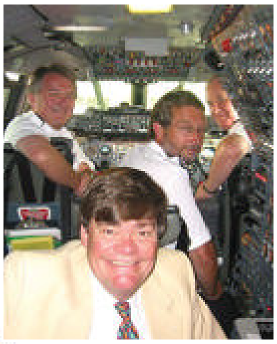
© Pline09

Undercarriage

The undercarriage was unusually strong due to the high angle the plane would rise to at rotation, just prior to take off, which put a tremendous amount of stress on the rear wheels in particular.

Cockpit

Concorde's were the last aircraft BA flew that required a flight engineer, seated in the cockpit with the pilot and copilot.



Mike Bannister (top left) piloted the first Concorde flight following the Gonesse disaster

Thrust-by-wire

Concorde was one of the first aircraft to use an onboard computer to help manage its thrust levels.

Nose

Concorde's nose drooped to help visibility on take off and landing and straightened in flight.

efficiently. This system was so successful that 63 per cent of Concorde's thrust was generated by these intakes during supersonic flight.

And yet Concorde still had to contend with the heat generated by supersonic flight. The nose – traditionally the hottest part of any supersonic aircraft – was fitted with a visor to prevent the heat reaching the cockpit while the plane's fuel was used as a heat sink, drawing heat away from the cabin.

Even then, owing to the incredible heat generated by compression of air as Concorde travelled supersonically, the fuselage would extend up to 300 millimetres, or almost one foot. The most famous manifestation of this was a gap that would open up on the flight deck between the flight engineer's console and the bulkhead. Traditionally, engineers would place their hats in this gap, trapping them there after it closed.

The Statistics

BAC/Aerospatiale Concorde

Manufacturer: BAC (Now BAE Systems) and Aerospatiale (Now EADS)

Year launched: 1976

Year retired: 2003

Number built: 20

Dimensions:
Length: 61.66m
Wingspan: 25.6m
Height: 3.39m

Capacity (passengers): Up to 120 passengers

Unit cost: £23 million in 1977

Cruise speed: Mach 2.02 (1,320mph)

Max speed: Mach 2.04 (1,350mph)

Propulsion: 4x Rolls-Royce/ Snecma Olympus 593 engines

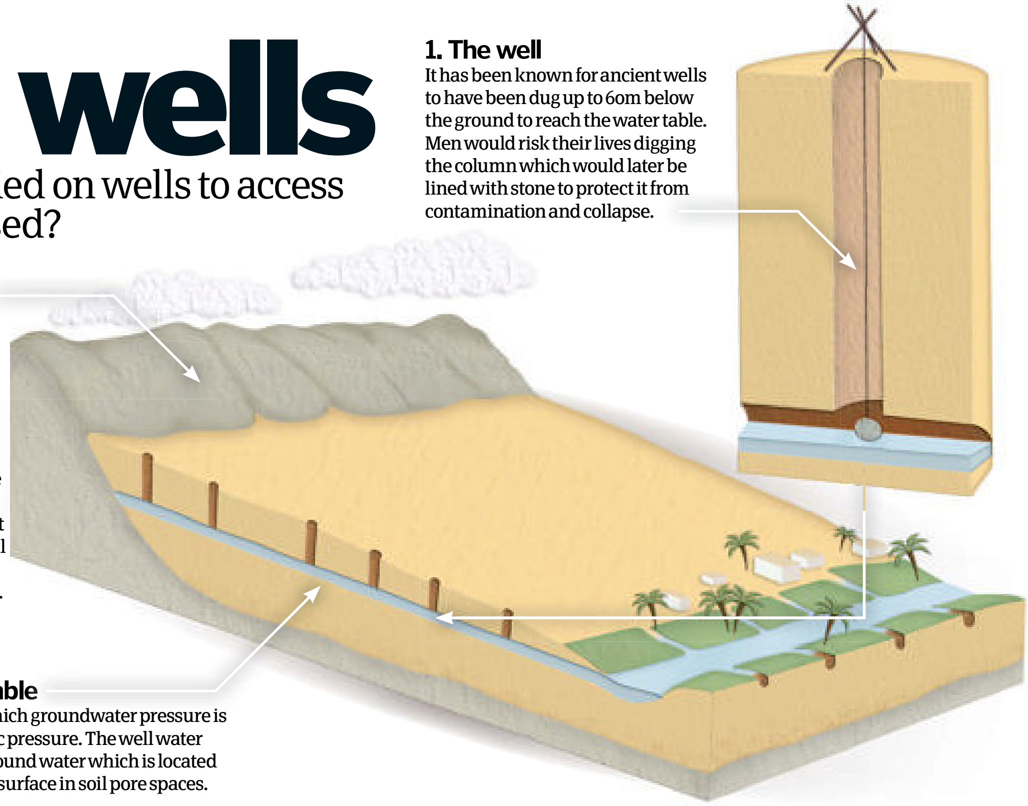
Ceiling: 60,000ft

Ancient wells

Before running water, people relied on wells to access water but how was the water raised?

The first form of wells were hand drawn or dug wells, which were constructed through excavation of men digging down through the earth to below the water table. The well wall and outer rim were lined with stones to avoid contamination and reduce the risk of people or animals falling in.

Early wells were pumpless so a pot (pail) attached to a rope was fed to the bottom to collect water and retrieve it. The earliest known wells are from the Neolithic period, with the oldest dating back to 8100-7500 BC. Today wells are created with advanced drilling equipment and feature pumps to draw the water to the surface.



1. The well
It has been known for ancient wells to have been dug up to 6m below the ground to reach the water table. Men would risk their lives digging the column which would later be lined with stone to protect it from contamination and collapse.

3. Clean water
The water was free from contamination because it travelled down from natural springs in the mountain underground, becoming part of the area groundwater. Therefore when built on an incline the well would access running clean water.

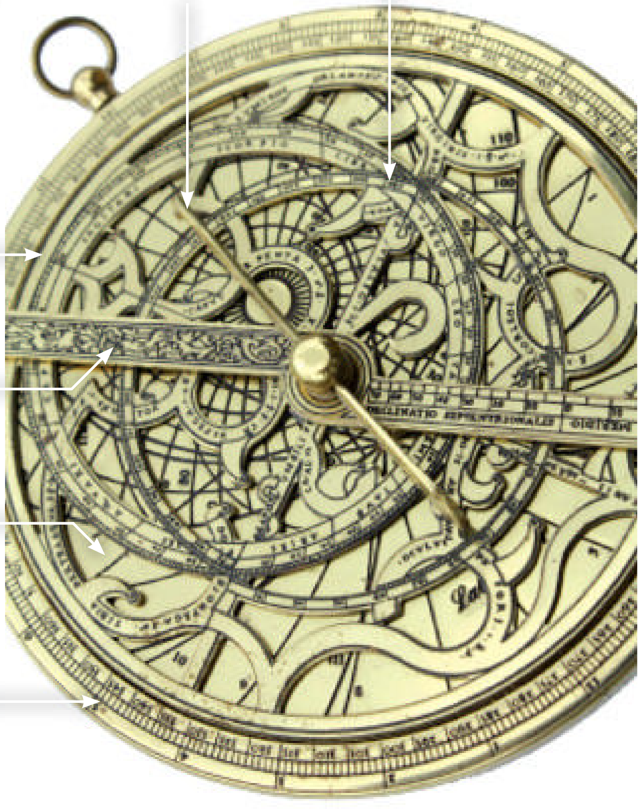
2. The water table
This is the level at which groundwater pressure is equal to atmospheric pressure. The well water would come from ground water which is located beneath the ground surface in soil pore spaces.

What is an astrolabe?

Although thousands of years old, the astrolabe still has its uses today in the fields of astrology and astronomy

Astrolabes were introduced to Europeans in the medieval era by Arabs as an astronomical instrument, but the device's origins have been cited as far back as 150 BC. When used correctly they can measure the height of the Sun or a star above the horizon.

Primarily intended for the purposes of astrology, geography, navigation and time keeping, the Europeans also used the device to form horoscopes. The tool itself consists of a disk (mater) which exhibits indented increments of time and/or degrees around the rim. This disk fits one or more plates (tympans) that are engraved with a circular projection of lines of equal azimuth and altitude to represent the celestial sphere above the horizon at that specific latitude. Above this then rests a rotating rete, a free moving framework showing the projection of the Sun's path. A complete rotation is equivalent to 24 hours.



5. Star pointer
The star pointer is placed at the position of their stereographic projection. By rotating the rete it is possible to decipher the position of the stars at their geographic location at that time of year.

4. Elliptical ring
This is used to chart the projection of the Sun's path. The interpreter can locate the Sun on that circle using a calendar to determine the Sun's longitude depending on what day of the year it is.

3. Rete
Placed on top of the plate is a rete, this is a freely rotating framework which is used to project the elliptical path.

6. Alidade
When held vertically the alidade can be rotated to chart the distance of a star along the line of sight.

2. Plate
The plates, or tymphans, are each intended for a specific latitude. The plate is engraved with a circular projection to represent the celestial sphere above the local horizon.

1. Mater
The mater is the main disk all the other parts rest upon. Around its rim are indented increments of time and/or degrees.

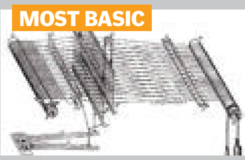
Head to Head

MOST MECHANICAL

1. Power loom

Edmund Cartwright created the first power loom in England way back in 1785.

MOST BASIC



2. Hand loom

The loom of choice before the industrial revolution, the hand loom allowed cloth and fabrics to be woven on a large scale.

MOST CLASSICAL

3. Warp-weighted

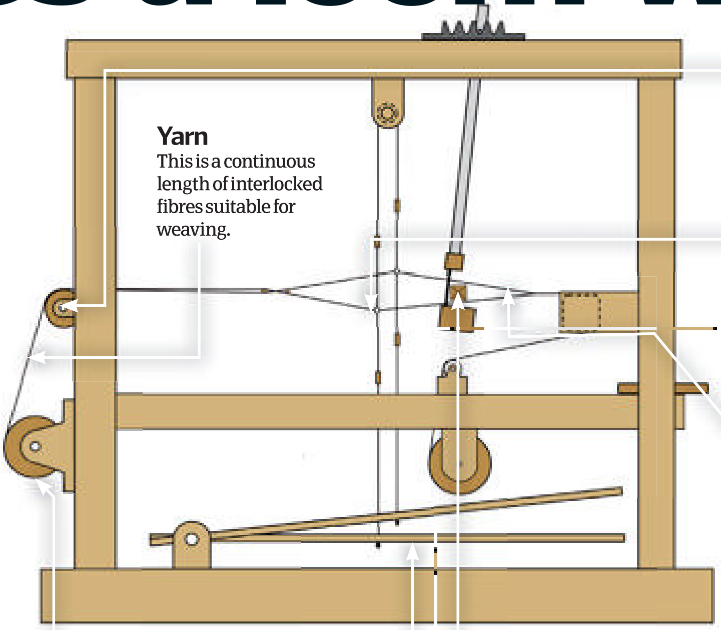
Similar in mechanics to the back strap loom, apart from the fact that it is arranged vertically and uses physical weights to keep the thread taut.

How does a loom work?

Integral to the art of weaving, the loom is an ancient but highly refined machine

Looms, while appearing rather complex, are actually fundamentally simple machines that work by holding two sets of parallel threads within a frame that alternate with each other as a cross thread is filtered through them carried by a shuttle (a wooden block in which thread can be stored pre-weave). By doing this cloths and fabrics can be weaved on a large scale quickly and in far greater numbers than if undertaken freeform by hand.

Since their initial construction in the 5th Century BC, the basic mechanics of looms have remained unchanged, with only a long succession of improvements introduced to the system. The most notable addition was the introduction of a drive-shaft power source, allowing for mechanised looms to be mass-produced and slowly evolved to the point of complete automation. Indeed, today it is argued by historians that the power loom was central to the development of the Industrial Revolution and has contributed greatly to the proliferation of large and high-quality fabrics worldwide. ⚙



Yarn This is a continuous length of interlocked fibres suitable for weaving.

Warp The set of lengthwise yarns through which the weft is woven.

Heddle A heddle is a cord or wire divider used to separate the warp threads for the passage of the weft.

Shed The temporary separation between the upper and lower warp yarn through which the weft is woven.

Weft The weft is the yarn that is drawn through the warp to create a fabric.

Treadle Operated by foot to produce a reciprocating motion in the heddle.

Shuttle A small tool that stores weft yarn while weaving. Shuttles are passed back and forth through the shed and between the threads of the warp.

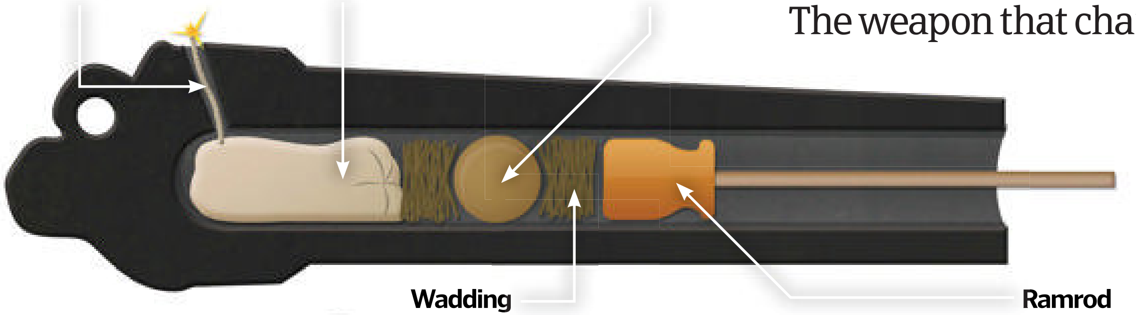
The cannon

The weapon that changed the nature of warfare

Early cannons were crude affairs with barrels made from wooden or wrought-iron staves held together by iron hoops. If the explosive mixture was too powerful it was likely to destroy the weapon rather than actually fire a projectile towards the enemy.

Barrel-making techniques were replaced by bell-making technology, with the production of cast brass cannons. Improvements in the casting of bronze cannons in the mid-14th Century meant that more powerful gunpowder mixtures – of sulphur, charcoal and saltpetre – could be employed with more deadly results.

In the mid-16th Century, the development of cast iron cannons brought down the cost of production and enabled an even wider deployment of this weapon. The use of cannons meant that castles and fortified buildings were no longer able to withstand long sieges. Large and complex star-shaped fortifications were introduced to cope with this danger; this had the effect of centralising power as only the richest could afford them. ⚙



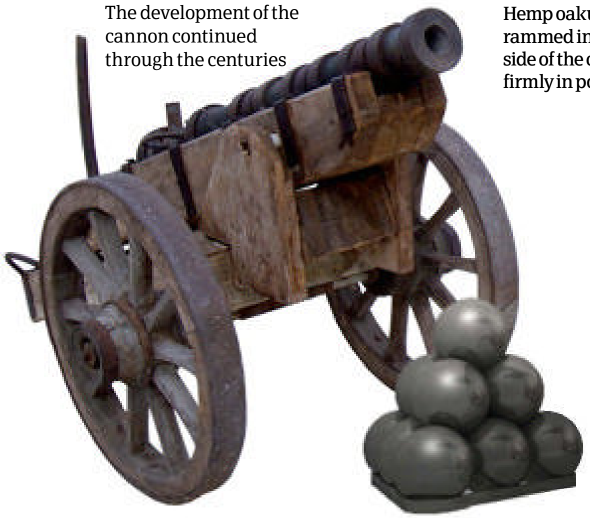
Torch-hole Gunpowder or a fuse is placed in the torch hole and ignited to fire the cannon.

Gunpowder In the late-15th Century water was added to gunpowder to form granules or mill cakes, making it easier to store and more efficient.

Cannonball Spherical, solid cannonballs were made from dressed stone, lead or iron.

Wadding Hemp oakum wadding rammed into the barrel either side of the cannonball keeps it firmly in position.

Ramrod When loaded, the ramrod is used to pack the wadding and cannonball firmly against the gunpowder. If not packed properly, the powder will burn instead of exploding.



The development of the cannon continued through the centuries

Ready, aim, fire!

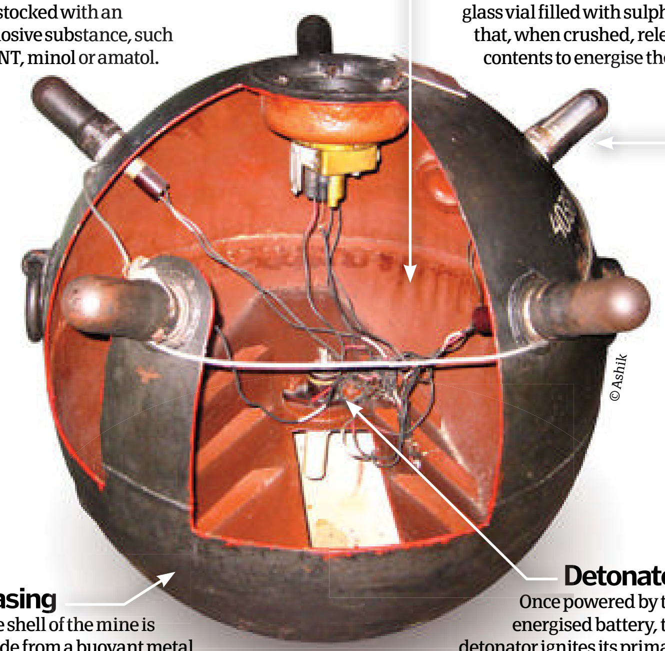
A contact mine exploding during World War II

Naval mines

How do they work and what do you need to do to make them detonate?

Naval mines are a contact-initiated type of explosive that can either be moored to the ocean floor by steel cables or left free to drift around unimpeded. Modern contact mines work by encasing a large quantity of an explosive substance – such as trinitrotoluene (TNT) – in a spherical metal shell covered with hollow lead protuberances, each containing a glass vial filled with sulphuric acid. When crushed by the hull of a ship or submarine, these protuberances, known as Hertz Horns, cause the vial inside to break and the acid to run down into a lead-acid battery stripped of acid electrolyte. The mixing of the freed acid with the battery energises it, triggering the electronic detonator and causing the mine's substance to ignite and explode.

Damage rendered to vessels by contact mines is three-fold. First, the explosive substance will cause direct damage – ie a hole in the hull will be blown open. This will cause severe damage to multiple watertight compartments and expose nearby crew to severe shrapnel debris. If the vessel is of small dimensions, an explosion of this type will likely sink it; if of large dimensions, it will cause it to become immobile. Second, when the mine explodes it will cause a bubble within the water, which – due to the difference in localised pressure – will collapse from the bottom. If this collapse occurs onto the ship's hull its force can puncture a metre-wide hole straight through the ship, killing all crew in its path instantly. Finally, contact mine explosions produce a shock wave that can cause any nearby vessel to resonate violently, causing engines to rip from their housing cases of large ships and breaking smaller ones apart entirely.



Explosive
The innards of the mine are stocked with an explosive substance, such as TNT, minol or amatol.

Hertz Horn
These lead protuberances contain a glass vial filled with sulphuric acid that, when crushed, release their contents to energise the battery.

© Ashik

Casing
The shell of the mine is made from a buoyant metal or plastic composite. They have a typical mass of 200kg.

Detonator
Once powered by the energised battery, the detonator ignites its primary material causing the explosive substance to detonate.

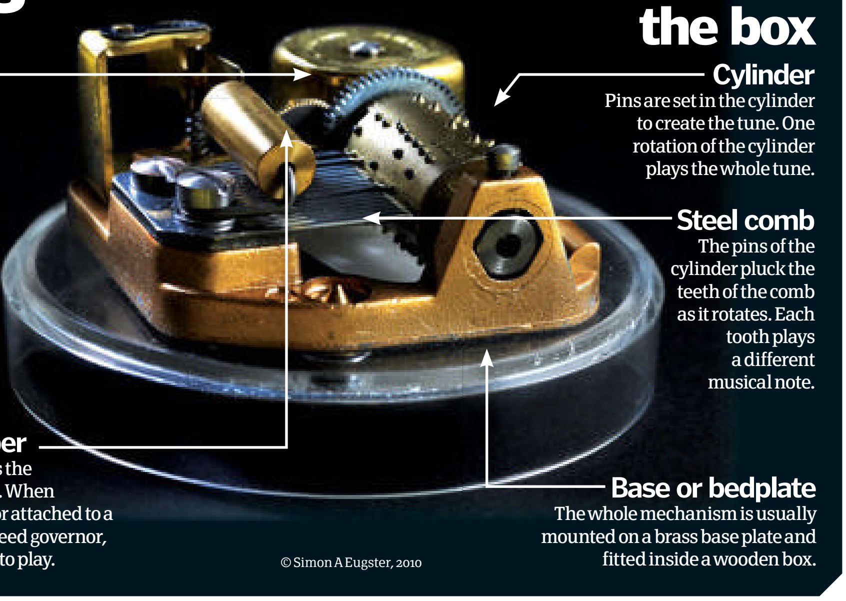
Early music boxes

Bringing automatic music to the masses

The music or musical box consists of a cylinder that is rotated by a small clockwork mechanism. Pins placed on the cylinder pluck the teeth of a stationary steel comb to create a tune (or 'air' as it is sometimes called). The movement works best in a wooden box as it acts as an ideal medium for transmitting and amplifying the sound.

Music boxes quickly came into vogue in the 19th Century when they were first made by watchmakers in Switzerland. These devices could become quite elaborate and employed multiple cylinders or discs to play complex tunes. Today, they are still popular as jewellery boxes and as novelties, and can be highly sought-after by collectors.

Inside the box



Spring housing and speed governor
A key is used to wind up the spring mechanism. When the mechanism is released the speed governor controls how fast the spring unwinds ensuring the correct rotation speed of the cylinder.

Cylinder
Pins are set in the cylinder to create the tune. One rotation of the cylinder plays the whole tune.

Steel comb
The pins of the cylinder pluck the teeth of the comb as it rotates. Each tooth plays a different musical note.

Weighted stopper
This brass cylinder stops the movement from playing. When this is tilted to the right or attached to a box lid, it releases the speed governor, allowing the movement to play.

Base or bedplate
The whole mechanism is usually mounted on a brass base plate and fitted inside a wooden box.

© Simon A Eugster, 2010

5 TOP GAMES ATARI 2600

Pac-Man
1 *Pac-Man* was adapted from an arcade game. It involves using the joystick to move Pac-Man through a maze. The object is to eat as many pac-dots as possible while avoiding ghosts.

Pitfall!
2 Created by David Crane, a former employee of Atari who cofounded Activision. You have to make Harry run and jump through jungles to grab gold and diamonds.

Missile Command
3 Another arcade game ported to the 2600, here you command missiles and protect yourself from attacks in the war between the planets Zardon and Krytol.

Demon Attack
4 Programmed for the 2600 by Rob Fulop – who cofounded Imagic and PF Magic – flying demons come from the sides of the screen to attack you on the planet Krybor.

ET: The Extra-Terrestrial
5 The aim of the game is to get ET to collect parts of an interplanetary telephone, so that he can phone home. You then have to race to catch a spaceship.

DID YOU KNOW? A new version of the 2600 was released in 1985, dubbed the '2600 Jr'

Atari 2600

For millions of people this was their first ever home computer

The Atari 2600 was launched in October 1977 as the Atari VCS (Video Computing System). The 2600 microprocessor-based games console used read-only memory (ROM) cartridges. Before its demise at the end of 1991, 40 million 2600s were sold worldwide and 900 games titles were created for it.

The console was supplied with an AC adaptor that plugged into the mains socket, and an aerial cable that connected the machine to the aerial socket of a domestic television set. It was controlled using the supplied joystick with a firing button on its side, and by switches on the console that could alter the difficulty level for each player and select games on the cartridge.

At the core of the machine are three computer chips, the 6532 RAM-I/O Timer (RIOT), MOS Technology 6507 central processing unit (CPU) and Atari's 6505 television interface adapter (TIA). All together, the system had 128 bytes of random access memory (RAM) and the games had a maximum memory of four kilobytes.

Although not as powerful as other machines of the period, its on-screen graphics were able to feature animated characters or objects that you could control in colourful settings and situations. This allowed greater flexibility for games programmers and more involvement and fun for all 2600 players.

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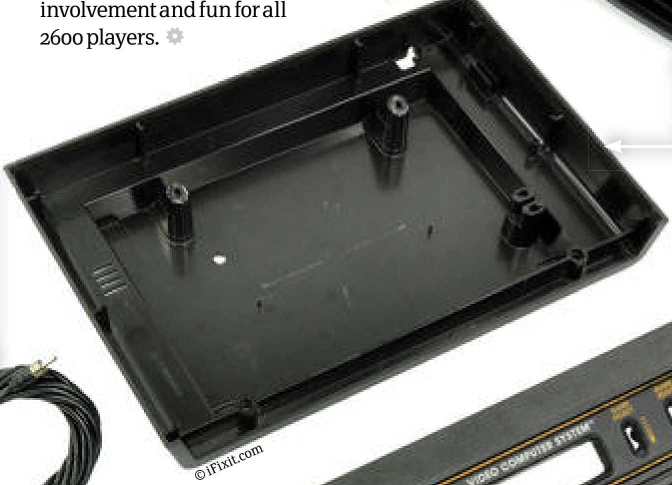
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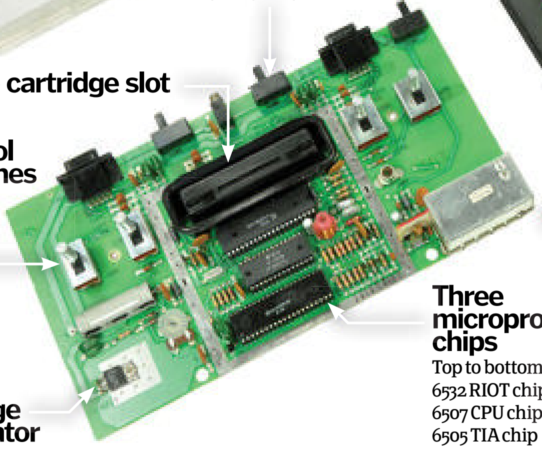
Base
Motherboard is screwed on to the base at a 30-degree angle.

Cover
Cover of four-switch model built between 1980 and 1982, with 'wood' veneer.

Aerial cable
Connects the 2600 to a domestic TV set.

Metal shield
This metal casing protects the electronic circuitry from electromagnetic interference (EMI).



Motherboard

Game cartridge slot

Four control switches

Voltage regulator

Three microprocessor chips
Top to bottom:
6532 RIOT chip
6507 CPU chip
6505 TIA chip

RF modulator

Inside an Atari 2600, Four-Switch Model

© Atari

Game player

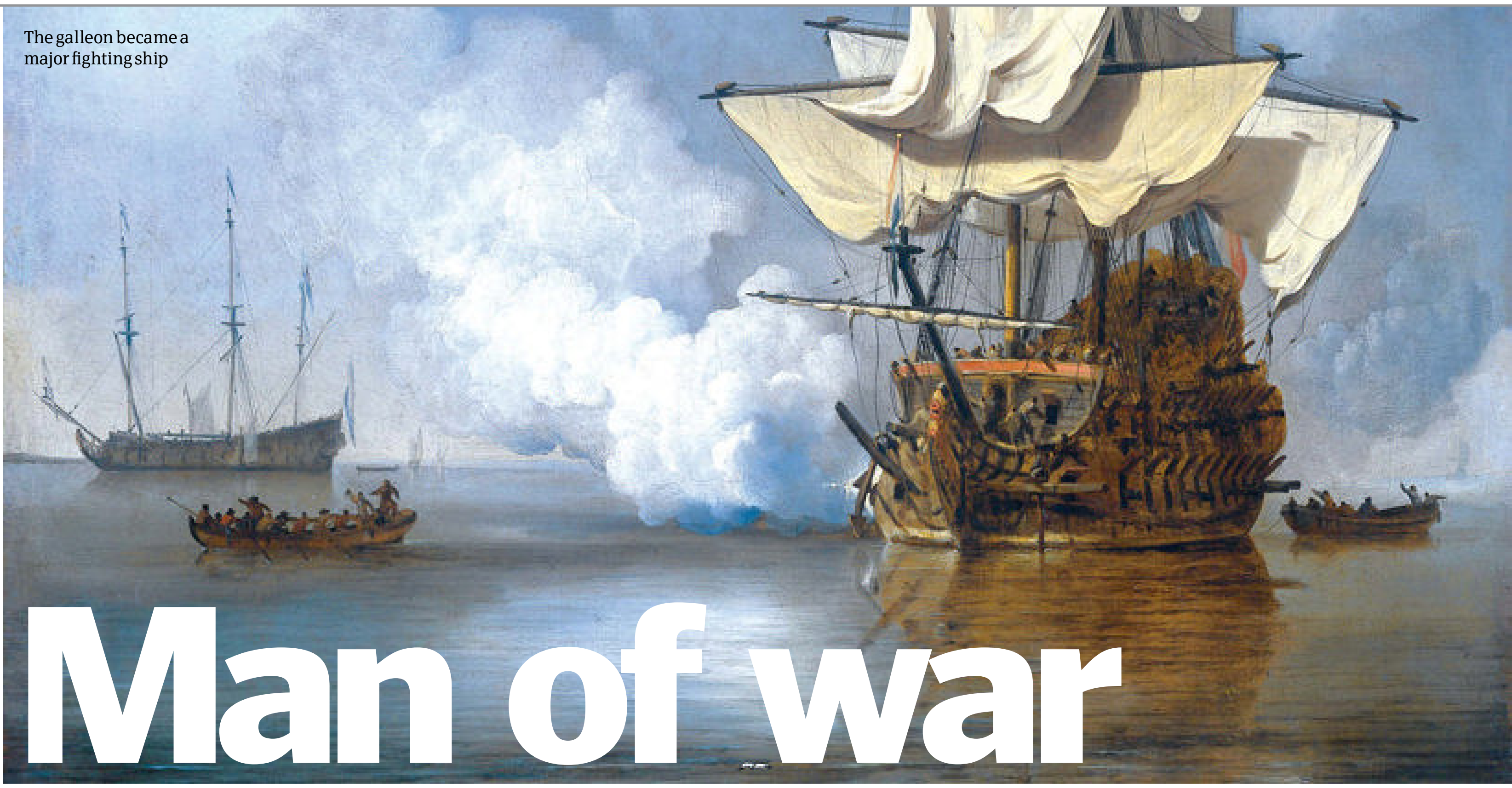
The 2600 was originally bundled with *Combat* and then with *Pac-Man* in 1982, and as its popularity grew many independent software companies cropped up to develop games for it.

Combat featured 27 videogames involving battles between tanks or biplanes with various options for one or two players. However, sales of the 2600 were disappointing until they adapted the *Space Invaders* arcade game in 1980. It was ideal for the system, as it involved fast action, colourful invaders who continually rained shots down onto you. Using the joystick, you dodged and shot at the invaders to get the highest score possible. People bought the 2600 just to play this game alone.

Atari was overly optimistic about sales of *Pac-Man*, and the film inspired *ET: The Extra-Terrestrial* adventure game. They sold well (7 million and 1.5 million respectively) but over-production and returns prompted a crash in the games industry in 1983 and with it came the end of the golden age of videogame production.

Learn more

For more info and images of the exposed Atari 2600, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.



The galleon became a major fighting ship

Man of war

Highly versatile and powerful ships capable of trade, diplomacy and combat, the man of war was the most prominent of armed ships from the 16th to 19th Century

Spanning a variety of ship designs from the 1500s to 1850, but typified by the galleon and ship of the line class of vessels, man of war ships were exemplars of ship-building expertise, delivering high manoeuvrability, storage capacity and firepower. They worked by taking the roundship and cog ship designs that had been the staple for European trade, transport and warfare since medieval times – both were powered by oars instead of sails – and added multiple masts, decks and cannons as well as more advanced rudder systems. These additions meant that long-scale voyages were now possible, opening up the largely uncharted world to nations and merchants looking to exploit the Earth's natural resources – events that lead to the great Age of Discovery.

One of the most notable man of war ship designs was that devised by Sir John Hawkins, treasurer and controller of the British Royal Navy for Elizabeth the 1st, and a key player in defeating the Spanish Armada in 1588. Hawkins' man of war – a name chosen by Henry VIII – was adapted from the Spanish galleon and Portuguese carrack and had three masts, was 60 metres long and sported a maximum of 124 cannons, four at the front, eight at the back and 56 on each side. Powered by sail and with a high (for the time) top speed of nine knots, Hawkins' man of war proved to be incredibly successful through the 17th and 18th Centuries. It was chosen and adapted by Sir Francis Drake on numerous expeditions.

The last man of war ships to be designed were the grade-1 listed ships of the line in the late 18th and 19th Centuries. These were colossal warships designed to be used in line of battle warfare, a naval tactic where two columns of opposing ships would try to out-manoeuvre each other to bring their largest cannons into range of the enemy. They were built primarily for combat and, as demonstrated on Lord Nelson's flagship HMS Victory – which sported a massive array of 32, 24 and 12-pounder cannons – were incredibly well-armed. For these first-rate ships of the line, trade was merely an afterthought, coming behind transport, diplomacy and combat in both functionally and priority.

HMS Victory: one of the finest man of war examples

5 TOP FACTS MAN OF WAR SHIPS

Caravel

1 The man of war developed from the earlier Portuguese trading ship the caravel, which was designed by Prince Henry the Navigator for exploration and to expand trade routes.

Galleon

2 During the 15th Century the caravel was adapted by the Spanish into the larger galleon-type ship. These ships were more heavily armed than their predecessors.

Henry VIII

3 The first English man of war was named by Henry VIII in the 16th Century, who used the ships to travel while performing diplomatic missions abroad.

1588

4 Heading up Henry VIII's naval development was John Hawkins, the ship builder and slave trader who went on to be knighted after the Spanish navy was destroyed in 1588.

Drake

5 The versatility of the man of war didn't go unnoticed, with explorer Sir Francis Drake adapting its design to develop a smaller more agile ship referred to as the frigate.

DID YOU KNOW? *The man of war replaced the European cog as the main trading vessel in the 16th and 17th Centuries*

Inside the man of war

What made this ship design so dominant for so long?

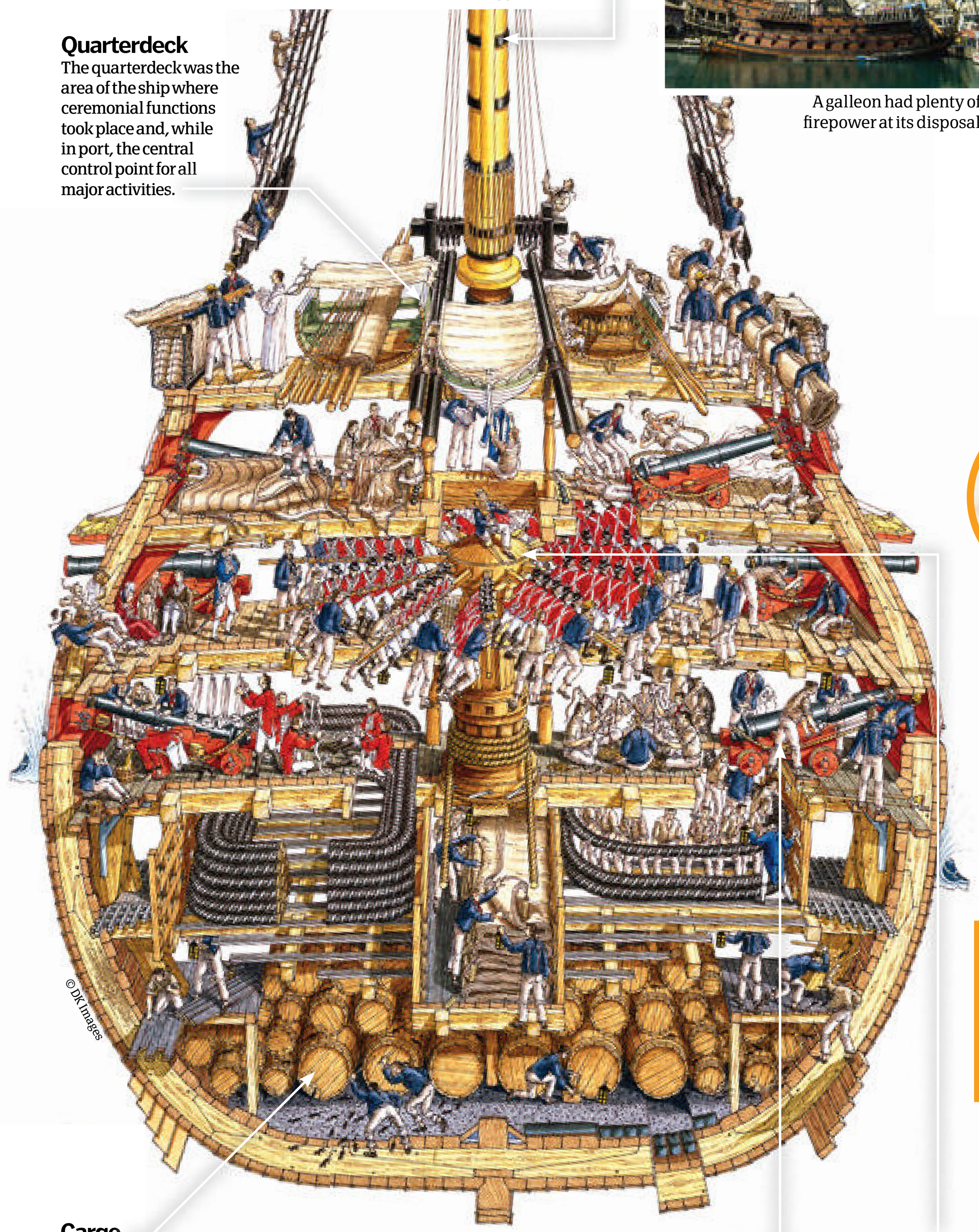
Masts

Common to man of war ships was a two- to four-mast design. These included the rear mizzen mast, central main mast and forward foremast. Not all man of war ships were square rigged, however.

A galleon had plenty of firepower at its disposal

Quarterdeck

The quarterdeck was the area of the ship where ceremonial functions took place and, while in port, the central control point for all major activities.



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Cargo

Early man of war ships were primarily used for exploration and trading even though they were armed. Their cargo was diverse due to the exotic locations they visited and included foodstuffs, precious metals and slaves.

Cannons

While various types of cannons were used on man of war ships, 2,540kg demi-cannons were popular thanks to their 490-metre range and six-inch calibre. Demi-culverins and sakers were also installed in various quantities.

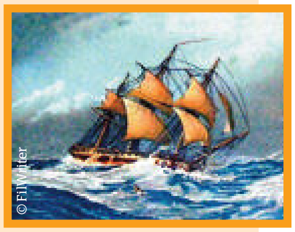
Anchor

Due to the large size of the ships used – with much room needed for their extensive cargo, cannons and crew members – the size of the anchor was also massive, requiring many men to winch it up from the ocean floor.

Man of war evolution

Follow the chronological development of the man of war

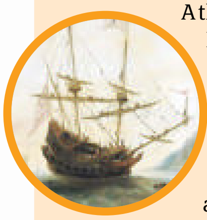
15th-16th Century (caravel)



© FilWriter

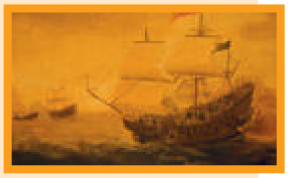
A small, highly manoeuvrable sailing ship developed in the 15th Century by the Portuguese, the caravel was the predominant exploration and trading vessel at the time operating in Europe and Africa. It was also used in naval warfare.

15th-16th Century (carrack)



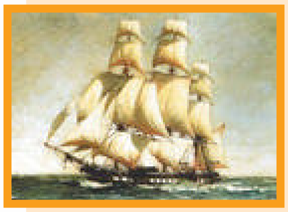
A three or four-masted ship used in Europe, the carrack is considered the forerunner of the great ships of the age of sail. Slightly larger than the caravel it could undertake longer trading journeys. It was armed with few cannons.

16th-18th Century (galleon)



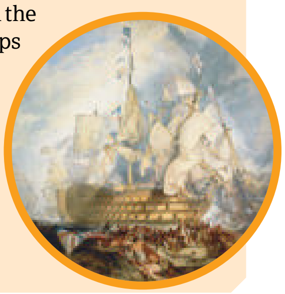
Used for both trade and warfare, the galleon evolved from the carrack, and included a lowered forecastle and elongated hull for improved stability and manoeuvrability. It had multiple cannons on multiple decks and became a major fighting ship.

17th-19th Century (frigate)



Smaller than galleons, frigates were similar to ships of the line but were faster and lightly armed. They were often used for patrolling and escort missions as well as protecting trade ships and trade routes with their cannons and crew.

17th-19th Century (ship of the line)



The largest ships built in the great age of sail were ships of the line, massive warships designed to engage with each other in line warfare. These were primarily combat vehicles and sported monumental firepower.

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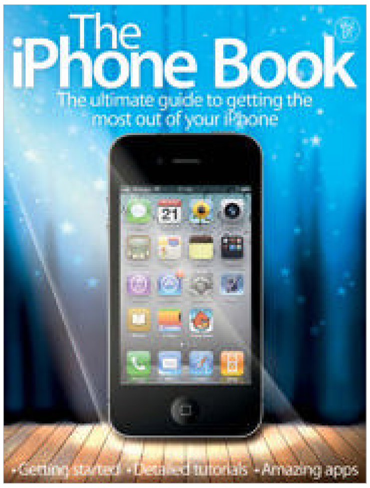
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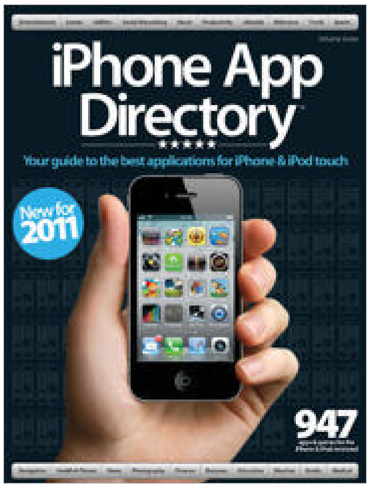
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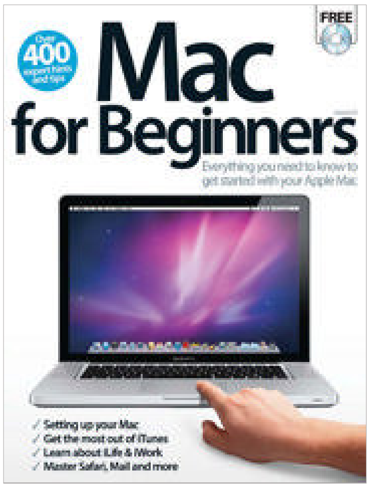
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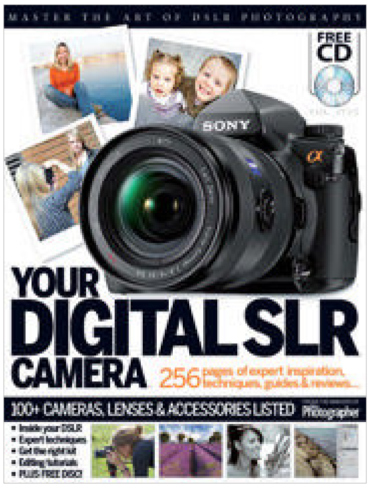
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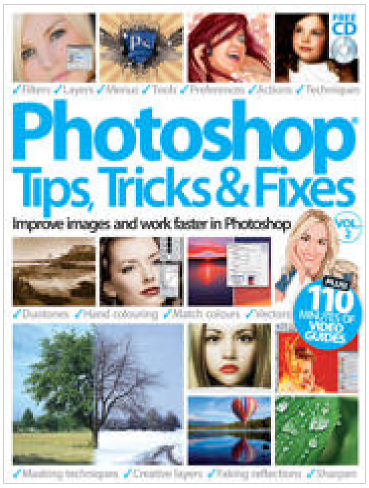
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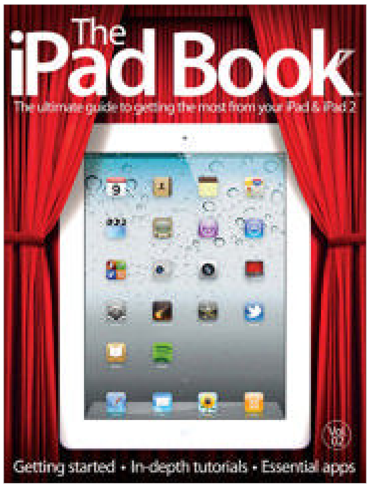
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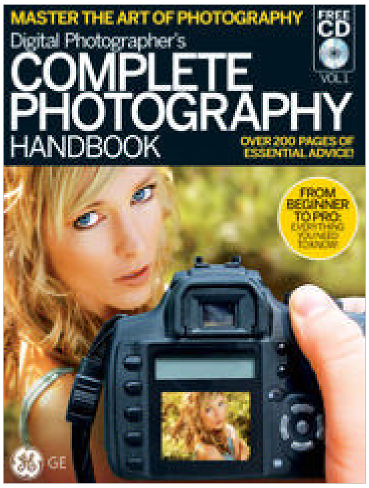
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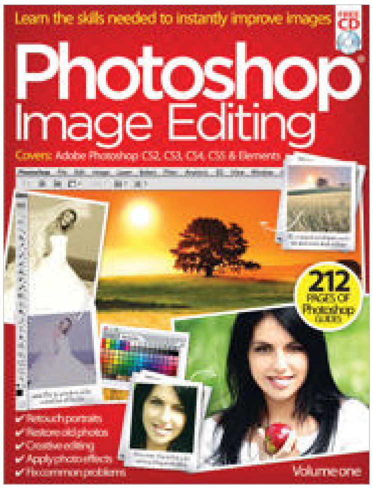
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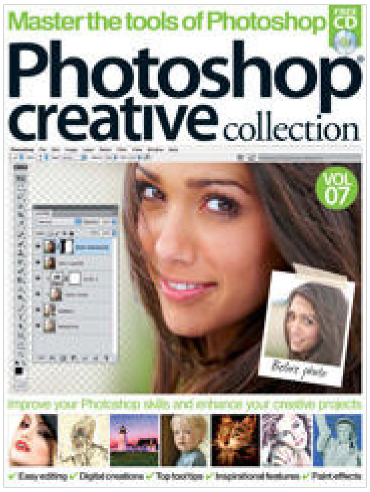
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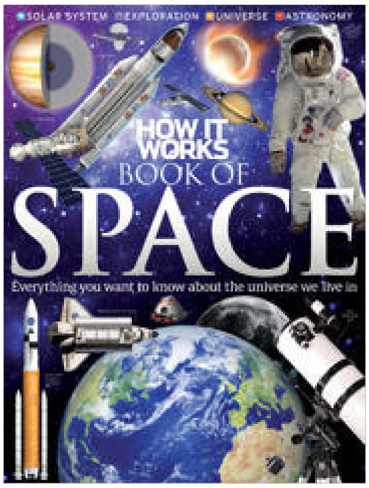
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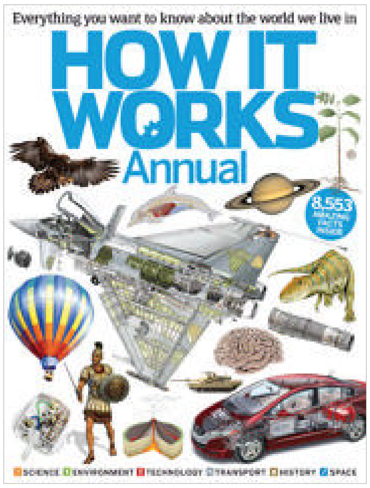
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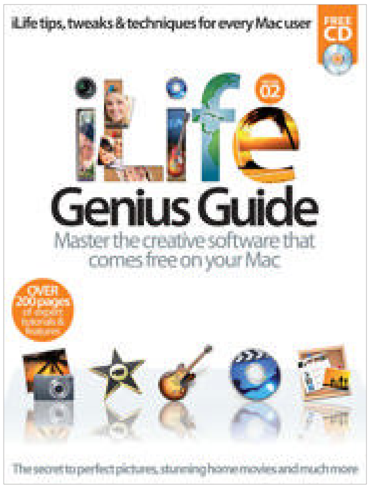
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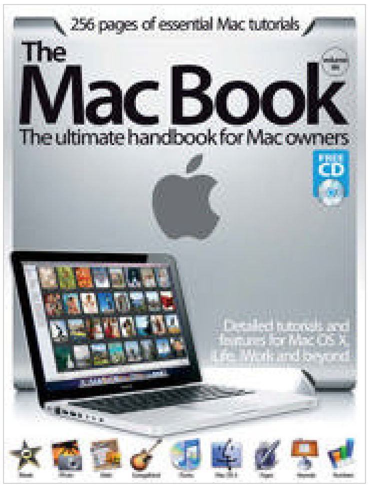
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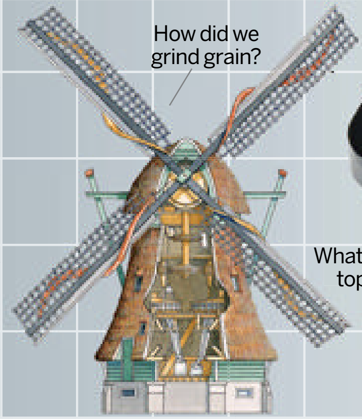
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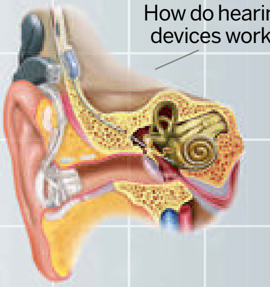
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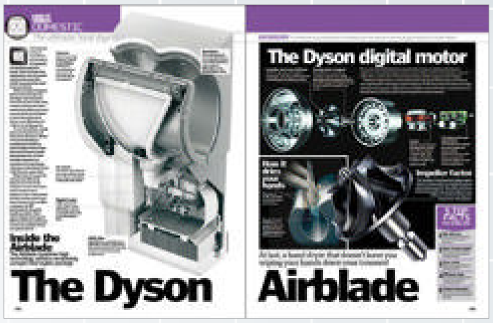
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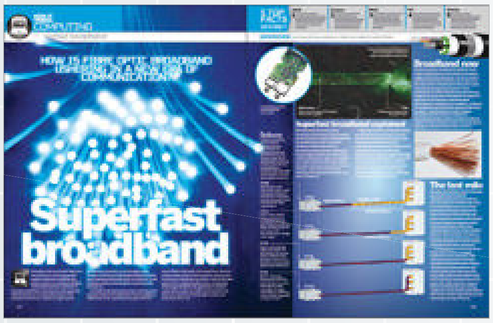
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